

SCIENCE TEACHERS' PERSPECTIVES ON THEIR EXPERIENCES IN A
GRADUATE PROGRAM IN PHYSICS EDUCATION AND
EFFECTS ON THEIR PRACTICE

by

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A dissertation submitted in partial fulfillment of the
requirements for the degree

of

Doctor of Education

in

Education

MONTANA STATE UNIVERSITY

Bozeman, Montana

July, 2011

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July 2011

ACKNOWLEDGEMENTS

I would like to acknowledge those people who supported me through the process of completing my dissertation. I would like to thank my committee – in particular Elisabeth Swanson for her tireless reviewing, editing, suggestions, and boundless positive energy throughout the entire process. Kathryn Cochran provided helpful tips and resources as I traveled through my Zone of Proximal Development. Gregory Francis invited me to observe first hand how Physics by Inquiry is practiced, and my teaching has not been the same since. Eric Brunsell, who, on a long bus ride through the high desert east of Los Angeles put me in contact with Elisabeth Swanson, and started this entire process some five years ago.

I would also like to thank Jennifer Miller for reading, editing, transcribing, and helping to bring this dissertation to life.

I would also like to dedicate this dissertation to my family, especially my beautiful wife Rebecca, who stood by me through this entire journey, even the rough parts. Finally, to my two daughters Lyra and Hailey, I began this process before you were born, and I want to thank both of you for your patience while daddy conducted this study. Now, we can play hide and seek on Saturdays.

This research was supported by the Center for Learning and Teaching in the West (NSF Award #0119786).

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ABSTRACT

Physics education research is showing that programs for physics educators should look different than traditional physics programs designed for other majors, but how? In the literature review preceding this sequential, mixed methods study, three exemplary, research based physics programs for practicing teachers are examined with respect to physics education research, especially the five principles for effective physics teaching set forth by senior physicist and physics education researcher E. F. Redish. This study provides an in depth examination of a well-established physics graduate program for practicing teachers at a small, midwestern university that is also measured against these same five principles: Constructivist, Context, Conceptual Change, Individuality, and Social Learning. In this setting, information was gathered in the form of a teacher survey, as well as through case studies of selected participants.

The results of this study affirm that graduate programs designed specifically for the development of physics teachers are, in fact, different. The data also indicates the value placed on, as well as the frequency with which the participants utilize these teaching approaches in their classrooms. Results showed that participants felt the program placed a higher emphasis on using multiple representations to convey information to students, as well as on teaching translational skills with respect to these representations. Smaller class sizes, more staff attention, and total immersion were cited as essential. Financial concerns with respect to some of the activities did occasionally arise. An area of concern was the lack of adherence to the Individuality principle, which states students have unique backgrounds and abilities that should be considered when designing a lesson. Assessing student prior knowledge when designing and implementing lesson plans also was not indicated as a frequent practice in the program, or in the teachers' own classrooms according to participant data.

In summary, according to participants' reports, the graduate program investigated modeled four of the five the principles proposed by Redish to a great degree, the exception being the Individuality principle. Based on the data contained in the survey, interviews, and portfolio submissions, recommendations for designers of future graduate programs for physics teachers were also made.

CHAPTER 1

INTRODUCTION

Introduction

In a report published by the Wisconsin Department of Public Instruction, Fischer & Swanger, (2005) indicate that there is a shortage of certified physics teachers in the state of Wisconsin, where this study takes place. They also state that this shortage has existed for many years, and is projected to continue and even worsen in future years. Other states have indicated similar problems. In an article by MacIsaac, Zawicki, Henry, Beery, & Falconer (2004), in the Journal of Physics Teacher Education, they note that within the state of New York, there is an intense demand for highly qualified and certified high school physics teachers. Carl Wenning (2004), a member of the faculty of Illinois State University states that in Illinois, high school administrators often search in vain for physics teachers. He goes on to say that many of these Illinois school districts are forced to staff a physics position with an under-qualified instructor, or in some cases, even an unqualified instructor. This practice has been happening all over the state of Wisconsin as well.

As a case in point, I began my career as a physics teacher without a certification. I was teaching out of my subject field (chemistry) because the district I worked in could not find a qualified physics teacher despite their best efforts. In my case, there was no question that the quality of instruction received by my students suffered as a direct result

of my lack of preparation, and as we will see, research indicates that my case was not unique. If a teacher is not adequately prepared to teach a subject such as physics (or anything else for that matter) it can be reasoned that this may have a negative effect on the quality of instruction received by their students. Therefore, it is essential that Wisconsin, like its counterparts finds new and creative ways to produce higher numbers of quality physics teachers.

Why is it so critical to increase the number of certified physics teachers?

This study is significant, because the shortage of physics teachers mentioned above is not an isolated incident, limited to a few cities or states. In fact, the problem appears to be nationwide. The US Department of Education (2002) predicts that the nation will need more than one million new teachers by the year 2010. Nearly half of the 2.6 million teachers currently employed in America's schools will leave teaching during the next few years due to a variety of reasons. On a national basis, more than 25% of all current teachers are over the age of 50, and many are approaching retirement (NCES, 2004). In an article published in *Educational Leadership*, Linda Darling-Hammond notes that despite these numbers, there is not a general shortage of qualified teachers overall. However, there is a major shortage in several fields such as special education, mathematics and physics (Darling-Hammond, 2001).

The growing shortage of qualified physics teachers has become more pronounced in recent years because, according to the American Institute of Physics' Statistics Research Center (Neuschatz & McFarling, 2001 in Wenning, 2004) many more high school students are now enrolling in physics courses. This information indicates that

there has been a steady increase in physics course enrollments nationwide since 1986. The numbers have risen from about 17% of all high school students taking physics in 1986 to over 30% in the year 2001. A large part of this percentage increase is because a growing number of girls and minorities are now choosing to take physics. While this certainly is good news, the lack of qualified physics teachers to work with these students is certainly reason for concern.

One reason for this concern is that many of the aforementioned minority students attend school in low SES urban districts, and, in a study conducted to assess the background and professional qualifications of high school physics teachers, it was stated that sharp contrasts in the presence of qualified physics teachers emerge clearly along lines of social class (Neuschatz & McFarling, 2000). In a research study to investigate the phenomenon of out of field teaching in American high schools, Ingersoll (1999) reported similar findings. Research suggests that the glaring disparity between urban and suburban teachers and their corresponding certifications may be one of the reasons why so few minority students are initially attracted to the sciences, and why even fewer are encouraged to take higher level science courses (Malcolm, 2006; Neuschatz & McFarling, 2000; Ingersoll, 1999). In an article referencing diversity in physics, Shirley Malcolm, the director of the education and human resources programs at the American Association For the Advancement of Science in Washington, D.C., attributes the small representation of minorities in physics classrooms to the quality of physics education received by these same students at the elementary, middle, and secondary school level (Malcolm, 2006). Because of the lack of teacher preparation for the teachers in schools

with large numbers of underrepresented students, most of these students graduate from high school with either no formal instruction in physics, or instruction carried out by an under-certified or even uncertified teacher teaching completely out of their field (Wenning, 2004). This is reflected in the fact that among those graduating from high school in 2000, only 26% of African-Americans and 26% of Latinos took any physics classes at all (Malcolm, 2006). Malcolm implies that the quality of physics education at the elementary and middle school levels, particularly in low SES districts sets the stage for these dismal high school numbers. Neuschatz & McFarling, (2000), go on to say that schools where the students are judged by the teachers to be financially better off than the average student are far more likely to have specialist physics teachers in their buildings than those judged financially worse off. And Malcolm (2006) adds that schools largely attended by minority students have much higher proportions of instructors teaching in fields where they are not certified or trained to teach. She believes that the overall scarcity of physics teachers across the nation is likely magnified in schools where the population is mostly African-American or Latino.

So the bulk of the certified physics teachers are not found in the inner city urban areas, and, in a matched pairs comparison research study on out-of-field teachers and student achievement, Dee & Cohodes (2008) found that the benefits of having a subject-certified teacher (for all subjects) appears to have a positive effect, raising the achievement level of students approximately 0.11 standard deviations for students in large, urban schools. At the same time, the effect was considered statistically insignificant for suburban schools.

What this implies is that the places where subject-certified teachers are needed most, are also the places where we find them the least. This could very well be contributing to the minority achievement gap, something that state and district programs resulting from federal No Child Left Behind (NCLB) legislation have tried to address for the past decade. For example, in 1999, the gap between White and Hispanic thirteen year-olds on the National Assessment of Educational Progress (NAEP) mathematics exam was 0.74 standard deviations, and between White and African-American students, it was 0.98 standard deviations (U.S. Department of Education, 2000a, 2000b). This is a significant gap, and in the Dee & Cohodes study, they found that having a subject-certified mathematics teacher increased student test scores by 0.12 standard deviations. They interpret these results to mean that just one year with a subject-certified mathematics teacher in a predominantly minority school could close the achievement gap in that subject by at least twelve percent (Dee & Cohodes, 2008). Hugo (2001) also points out that in a study conducted by Clifford Adelman, a Senior Research Analyst for the U.S. Department of Education entitled: *Academic Intensity, Attendance Patterns, and Bachelor's Degree Attainment*, it was found that the impact of a rigorous high school curriculum complete with a high quality support network was by far the most substantial pre-college indicator of academic success for both African-American and Latino students (Adelman, 1999). So having a teacher in front of the students who is very familiar with both their content area, and the cultural background of the students they are working with could be pivotal in determining the success rate of the students in his/her classroom.

One alarming statistic is that these achievement gaps seen in the United States seem to be among the largest in the world. In fact, in a study of comparing empirical, cross-national trends in international mathematics and science study data concerning teacher quality, opportunity gap, and national achievement in 46 countries, it was stated that the national level of teacher quality overall in the United States was similar to the world average, however, the opportunity gap in students' *access* to qualified teachers between low SES students and high SES students was among the largest in the world (Akiba, LeTendre, & Scribner, 2007). These researchers go on to state:

The importance of access to quality public education [is] one of the few mechanisms available in the United States to counterbalance the transmission of social status and privilege. Access to high quality teachers, then, appears essential to mitigating long-term social inequality in the absence of other policy levers. Unlike other nations with more developed social welfare or youth ministries, the United States traditionally has relied on school-based measures to ameliorate the effects of poverty. (p. 370)

So it appears that the limited supply of qualified teachers we have in fields such as physics seem to be concentrating themselves in districts where the students are perceived as economically above average. This no doubt is leaving the students in the lower SES districts without qualified, certified teachers in many fields including physics. Ingersoll (1999), points out several of the possible consequences of having an out-of-field teacher in the classroom when he says:

The limitations imposed by a lack of subject background on a teacher's ability to teach for critical thinking and to engage the students interest in the subject... [and] the assignment of teachers to teach in fields in which they have no training could change the allocation of their preparation time across all of their courses—decreasing the amount of time they spend preparing for other courses in order to prepare for the one(s) for which they have no background. (p.29)

In a study to assess the background and qualifications of American high school physics teachers, Neushatz & McFarling (2000), found that only about 61% of public high school physics teachers are endorsed to teach physics, and only about one third of them actually majored in physics or physics education. This means that the remainder of high school physics courses are no doubt being taught by math, chemistry, or even non-physical science teachers who are teaching completely out of their field. This was where I began my teaching career. I was certified in chemistry, biology, and general science, but I was not certified in physics. The position of the district I worked in was that since I was a science teacher, and “science is science,” like any certified science teacher, I should be able to cover all the disciplines. While reviewing the literature, I discovered that my district was not alone in this mode of thinking. Wenning (2004) states that

Recent efforts by the Illinois State Board of Education to certify “highly qualified” teachers of science... [involves] plans to replace the current endorsement system (chemistry, physics, biology) with a system under which all new science education graduates are permitted to teach introductory courses in any area of science... after passing a test with 67 science core questions on it, along with 33 designation area questions...[this] is seen by the Certification Board as an appropriate qualifier for teachers to teach all areas of science regardless of their formal preparation. (p.26)

Also, the National Council on Teacher Quality (NCTQ) indicated that as of 2010, thirty-nine of the fifty states have a science certification system similar to the Illinois system described above (National Council on Teacher Quality, 2010). NCTQ argues that in this system, all branches of science are treated the same; or at least as though the same individual can readily teach anatomy, plate tectonics, titration, and simple harmonic motion. The “general science” certification, argues NCTQ, does not guarantee the

teacher has mastered the subject they will be teaching, or subject-specific lab and field skills, and pedagogical techniques.

Ingersoll (1999) mentions that the under-qualification of physics teachers seems to have a definite negative impact on student performance, although other researchers are not so sure about just how large of an impact it really has (Dee & Cohodes, 2008). However, it cannot be ignored that only 18% of our nation's twelfth grade students scored at the proficient level or better on the 2000 NAEP science test (NCES, 2001), and this number has actually fallen from 21% in 1995. Something needs to be done to help create the next generation of physics teachers. More students are choosing to take physics, and many of these students are in low SES, high poverty school districts. Research has shown that students from these areas in particular need an enthusiastic, caring, and *highly qualified* teacher to help close the ever-present achievement gap they are currently facing.

What is the higher education community doing to address this growing problem?

Recently, a trend has been occurring across much of the student learning literature. This trend is indicating a shift away from looking at how best to arrange the content being taught, in favor of determining the best way for students to experience the learning situation as put forth in an article discussing various methods for teaching physics (Linder, Fraser, & Pang, 2006). Furthermore, there have been many studies conducted that suggest that teachers will teach as they themselves have been taught (McDermott, Shaffer, & Constantinou, 2000; Adamson, et al., 2003; Tiberghien, Jossem, & Barojas, 1998; Wood, 2002; Roth-McDuffie, McGinnis, & Graeber, 2004 and many

more). The American Physical Society, American Association of Physics Teachers, and the American Institute of Physics have all identified pre-service teacher preparation as a key issue for the physics community. In an executive summary on recent efforts by a group of physics teacher education projects working collaboratively, the Physics Teacher Education Coalition (PhysTEC) indicated that schools in the United States hire about 1200 physics teachers each year. However, only about one third of these new hires have a physics degree (Physics Teacher Education Coalition, 2009). In addition, Neuschatz and McFarling (2000) make the point that better trained teachers are able to attract more students to physics, and this allows them to use their training in a variety of creative and effective ways. They mention a highly trained physics teacher being able to teach a more diverse curriculum including advanced courses, and courses aimed at reaching children with lower level math skills. They point out that a specialized physics teacher costs the same as someone teaching out of field, so it makes sense to provide the students with a certified physics teacher whenever possible, and this will cause the total percentage of students in the district taking physics before they graduate to increase. These same researchers go on to mention:

The situation of the individual teacher can have a profound effect on the physics experience for a school's entire student body. The students of a teacher who feels well prepared and well supported have a very good chance of enjoying an exciting and stimulating introduction to physics. By the same token, a reluctant or poorly qualified teacher can discourage even the most enthusiastic students. (p. 102)

Other research has found that teachers develop a strong sense of empowerment when they have a sound conceptual understanding of the science content they are expected to teach, and this greatly enhances their ability to effectively deal with unexpected situations

that may arise in the classroom according to McDermott, Shaffer, & Constantinou, (2000), in their paper discussing the merits of using alternative methods for the teaching of physics.

Koponen, Mantyla, & Lavonen, (2004) state that the consensus seems to be that listening to lectures about physics structures, epistemology, and methods is not enough. These discussions need to be supplemented with teaching and learning strategies which will assist pre-service teachers with building their scaffolding and de-fragmenting their knowledge about physics. These students need time to collect their already acquired pieces of knowledge and compile them into a coherent whole. What is needed, argues Koponen is not only competence in physics core concepts for these pre-service teachers, but also competence in its didactics and pedagogy. They are part of a program in Finland that is exploring alternative methods to providing physics instruction to secondary level teachers.

Three physics programs created to impart both substantial and sustained conceptual change in the minds of their students will be discussed in detail in Chapter 2 of this paper. Each of these programs will be examined through the lens of five teaching principles developed by long-time physics education researcher E. F. Redish. The programs are Physics by Inquiry, which has its roots at the University of Washington, Modeling which comes to us originally from Arizona State University, and The Physics Suite developed by Redish and his team at the University of Maryland. The certification and master's degree program developed by the Physics Department at the University of Wisconsin – River Falls was selected as the context for the this study, and was found to

include many aspects of Redish's principles and to have many similarities with the three larger-scale programs described in Chapter 2.

The Physics Department at the University of Wisconsin-River Falls has been addressing the need to supply the nation with certified physics teachers for twenty-five years. Through a summer program which started in 1986, elementary, middle, and high school teachers can take a series of physics courses to either increase their knowledge of physics, earn a Wisconsin Department of Public Instruction physics endorsement on their license, or take classes over several summer sessions to earn a Master of Science Education degree with a physics emphasis. The purpose of this research study was to answer the following questions:

1. What components are present in a program specifically designed to develop physics teachers' understanding of physics content and pedagogy?

As we will see, Chapter 2 indicates that there are certain core principles that, when embodied and incorporated into educational practice, seem to assist the educator in producing deep and lasting conceptual change in the mental models of their students.

2. What aspects of a program specifically designed to develop physics teachers' knowledge of physics content and pedagogical skills were present in the target program in this study?

Through a variety of data collection methods including surveys, interviews, and portfolios, I searched for evidence of the five principles in the preparation process of the physics teachers from the River Falls program.

3. What aspects of a program specifically designed to develop physics teachers' content knowledge and pedagogical skills were viewed as important or useful by participants?

4. What aspects of a program specifically designed to further physics teachers' practices were used in the classrooms of participants?

It is probably safe to assume that the designers of physics teacher professional development or graduate programs strive to select methods supported by physics education research that result in lasting positive change in the students being taught. However, it is not immediately clear to what extent experienced teachers view these practices as valuable, and transfer them into their own classrooms. The study examined the degree to which elements of the five principles, found in the River-Falls program, were experienced by participants at UWRF (Research Question Two), valued by the participants (Question Three), and present in the teaching practices of the participants (Question Four). As part of the case studies, I also noted effective methods the teachers used that were not part of the UWRF program, but that the teachers discovered through other means were effective for fostering conceptual change in the minds of their physics students.

This study used sequential mixed methods approach, starting out with a survey that provided quantitative data, and was administered to a large group of former and current UWRF program participants at the start of the study. From the survey respondents, a smaller group of case study volunteers were selected for interviews and portfolio submissions that were qualitative in nature. By using and comparing results across multiple data collection methods, it was hoped that a clearer picture would emerge about what current and aspiring physics teachers have been exposed to in their physics teacher professional development and graduate work, what they feel is important in their

teaching, and what aspects of their training they choose to, or are able to use into their classroom practice.

CHAPTER 2

LITERATURE REVIEW

Introduction

In this chapter, I will present a framework for a research-based method of conveying physics information to our students. The framework is still being constructed by individuals around the world involved in physics education. Collectively, they call themselves *Physics Education Research* groups (PER groups). These educators and researchers have been working for decades attempting to create a more complete picture of physics instruction. It is their hope that as methods of physics instruction born out of their research efforts are refined, more colleges and universities will utilize them in the training of their undergraduate physics students; particularly the students aspiring to become physics educators. It will be these educators who will then bring these fresh ideas, methods, and perspectives into their middle and high school classrooms to hopefully bring a deeper understanding of physics and physical principles to their students.

In addition to looking broadly at several of these research based programs, we will take a more detailed look at one in particular; The Summer Physics Certification Program at the University of Wisconsin – River Falls. The River Falls program has been chosen because I will use graduates from it to investigate the extent to which the research based teaching methods being taught at the university have been carried over into the high school classroom, as well as the factors that facilitate or prohibit this transfer.

The framework I will use to organize much of the material in this literature review comes from E. F. Redish in his book entitled “*Teaching Physics with the Physics Suite.*” Though originally a nuclear physicist, Dr. Redish has been actively involved in physics education research since 1982, and in 1992 research in physics education became his sole study interest. Professor Redish is a fellow of the American Physical Society, the American Association for the Advancement of Sciences (AAAS), and the Washington Academy of Science. He has also received awards for his work in education from the Washington Academy of Science, the Maryland Association for Higher Education, Dickinson College, Vanderbilt University, and the Robert A. Millikan Medal from the American Association of Physics Teachers (AAPT). In 2005, he received the National Science Foundation (NSF) Director's award as a Distinguished Teaching Scholar. One of his primary research interests has been to study the cognitive modeling of student understanding in physics.

Redish stresses that if we can somehow tease out elements from the students' reasoning that are correct, we can then build on these elements to help students reorganize their thinking and redraw their conceptual maps.

In order to accomplish this task, he has drawn from both education research in general, and physics education research specifically. From his work, he has arrived at a list of five general principles centered on what occurs in the typical physics classroom. It is from these five principles that a picture of what a competent physics teacher looks like begins to emerge. In the pages that follow, several university programs will be examined through the lens of these principles. These programs are utilizing methods that differ to

varying degrees from the classical teacher-centered method of teaching introductory physics at the university level.

These programs all share the belief that there may be a better way to assist physics students, specifically those students aspiring to become physics/science teachers at the K-12 level, to reach a deeper level of understanding of the content they are exposed to. Since it is widely believed that teachers teach as they have been taught, it is the hope of each of these programs that the methods they employ to produce a deeper level of understanding in their students will then be utilized in the K-12 setting when these students leave their respective programs and begin their teaching careers. I have chosen Redish's five principles for developing competent physics teachers because they are consistent with other evidence I have found in my review of the literature, and they also figure prominently in several exemplary physics teacher training programs. The principles will be briefly described here, and a research based set of criteria required to show evidence of utilizing each of the five principles will be provided. We will then search for evidence of the five principles in the aforementioned programs. We will also search for evidence of the carryover of these principles into the classrooms of high school physics teachers trained in one program studied for this dissertation.

The five principles proposed by Redish as a framework for designing or evaluating physics programs are:

1. The Constructivist principle
2. The Context principle
3. The Change principle

4. The Individuality principle
5. The Social Learning principle

These principles, their alignment with the research findings and experiences of others in the physics education community, and their relationship to this study, are all introduced in the next sections of this literature review.

Redish has formulated some interesting arguments as he has applied cognitive science to the teaching and learning of physics. According to Redish (2002):

The key to understanding student reasoning is understanding the *patterns of association* that activate knowledge elements. In general, a pattern of association of knowledge elements is sometimes referred to as a *knowledge structure*. A pattern that tends to activate together with a high probability in a variety of contexts is often referred to as a *schema* (p. 24).

When a schema is robust and reasonably coherent, Redish uses the term *mental model* to describe it. Occasionally, students' patterns of association concerning physical phenomena are extremely robust—they occur often enough in a wide array of contexts for us to refer to them as mental models. Often, they contain inappropriate generalizations, fusions of concepts that are actually distinct from one another (such as failing to distinguish between heat and temperature), or separations of situations that should be treated uniformly such as treating a box sliding across a floor and a rapidly moving baseball using different rules). Usually these concepts are not “just wrong.” Often these incomplete and/or incorrect conceptions are valuable and effective at getting students through their daily lives. In many cases, these conceptions have glimmers of truth that can help students build more scientific and productive concepts if they are built upon appropriately (Redish, 2002).

Redish comments on a study conducted in 1993 by diSessa. He calls it “Perhaps the most extensive and detailed analysis of student reasoning in introductory physics.” The study, entitled “Toward an Epistemology of Physics” analyzes the growth and development of student reasoning in an introductory calculus based physics course taught at MIT. Though the study involved only twenty students, Redish states that the care and depth of the analysis makes it worthy of attention, and he also tells us that similar results have since emerged in much broader populations of physics students.

DiSessa investigated people’s sense of “why things work the way they do.” What he discovered was that many students, even *after* instruction in physics, often come up with simple, broad statements that describe the way they think things function in the real world. They often cannot give a “why” for their answers... they simply say “That’s just the way things work.” This observed phenomena comes as no surprise to the seasoned physics teacher who, for example, tells her students that all objects fall to earth at the same rate, demonstrates the fact that all objects fall to earth at the same rate, has the students conduct an experiment to verify that objects do, in fact, fall to earth at the same rate, has the students verbalize the fact that all objects fall to earth at the same rate, and finally has her students solve mathematical problems that show objects falling to earth at the same rate. This physics teacher then confidently asks a qualitative question on the unit exam that asks which object, when allowed to fall a distance of one meter would hit the ground first, a bowling ball or a pencil. Upon grading the exam, however, the confident physics teacher discovers that many of her students indicated that the bowling

ball would hit the ground first. Despite her best efforts, something was still lost in translation.

When a student gives a simple explanation to a phenomenon, but cannot explain the reason why it works, diSessa calls this explanation a *phenomenological primitive*. Redish (2002, p.27) points out that “primitives tend to be linked directly to a physical situation. They are *recognized* in a physical system rather than derived by a long chain of reasoning.” What this means is that the student “shoots from the hip” to explain what they are observing, rather than constructing a logical reasoning framework. Redish comments that these primitives are not wrong or right in themselves. Often times they are correct *in some circumstances* (in our example, a heavier object does fall to earth faster than a lighter object... if we take air resistance into account). The trouble starts when the student attempts to apply the primitive to *all* situations, some of which may not be correct, and cannot see the difference.

One of the critically important aspects of physics education is the analysis of these primitives and how the students map them onto the physical phenomena they observe. Using the results of the diSessa analysis, Redish states that the critical realization that arises from analyzing student responses in this fashion is that students’ common naïve conceptions are not simply “wrong.” They are based on correct observations but may be generalized inappropriately or mapped onto incorrect variables. Vosniadou (1994) calls this inappropriate mapping a synthetic model. Redish stresses that if we can somehow tease out elements from the students’ reasoning that are correct, we can then build on these elements to help students reorganize their thinking and redraw

their conceptual maps. We will now examine each of the five principles in greater detail, and discuss several programs and their attempts to implement them.

1. The Constructivist Principle

Definition

“Individuals build their knowledge by making connections to existing knowledge; they use this knowledge by productively creating a response to the information they receive” (Redish, 2002, p.30).

Elaboration

This principle is saying exactly what both constructivists and cognitive scientists tell us. In order for students to learn something new, it has to be related in some way to something they already know. Bodner (1986) reminds us that Piaget believed “knowledge is constructed as the learner strives to organize his or her experiences in terms of preexisting mental structures” (p.873). Renner, Abraham, & Birnie (1986) state that Piaget defined a mental structure as “a system of transformations and content [which] represents the beliefs we have about the world” (p.620). Piaget believed that the construction of this mental structure occurred while the student went through the processes of assimilation, disequilibrium, accommodation, and organization. These terms will be discussed in greater detail in the next section, where we look at examples of using the Constructivist Principle in the classroom. One of the examples, the Learning Cycle, developed by Robert Karplus leads students through Piaget’s processes of knowledge construction. Exploration, stage one of the Learning Cycle, begins the

process by providing experiences that lead to assimilation and disequilibrium. The second stage, called Concept Invention, assists the student in the process of accommodation. The student then “pulls it all together”, a process called organization, in the third stage of the cycle, called Expansion.

Bodner (1986) wraps this up succinctly when he says that “The constructivist model can be summarized in a single statement: Knowledge is constructed in the mind of the learner” (p. 873). Driver (1989) adds to this statement when she says “What pupils learn from lesson activities... depends not only on the nature of the tasks set, but on the knowledge schemes that pupils bring to these tasks” (p.84). She also reminds us that learning about the world does not occur in a social vacuum. Students utilize such things as language and culture to help them make sense of the world around them. It is through constant social exchanges that students are checking to see if others close to them see the world in the same way they do. Whether other people affirm or disagree with our ideas in classroom discussions has a part to play in shaping the construction of a mental structure (Driver, 1989).

Examples of the Constructivist Principle

Constructivist examples of physics instruction involve allowing students to experience a physical phenomenon by having them first explore it through direct experience, then have them construct a concept, and finally culminate the learning activity with a extension of the concept to other situations or contexts, which will be discussed when we examine the Context Principle. This sequential method of introducing unfamiliar material to the science students follows the work of Robert

Karplus, a Berkeley physicist and science educator. It is known as the Learning Cycle, and it has its roots in the developmental learning theories of Piaget.

The Learning Cycle consists of three phases. The first of which is called *Exploration*. Here, the students gather data and make observations. Through a carefully designed and orchestrated process, the data and observations are specifically designed to place the students in a state of disequilibrium. That is, what they are seeing does not match up with what they expect to see, or it conflicts with their preexisting mental model for the situation they are observing. Redish (2002) refers to this process as creating “cognitive conflict.” In some instances, rather than placing the student in a state of disequilibrium, the teacher listens carefully to what the student has to say, and picks out certain things that are correct. The teacher then uses these correct statements to build bridges to new material. This idea will occur again when we discuss the Change Principle. Certain aspects of the five principles overlap with one another. As we will see throughout this literature review, utilizing methods such as cognitive conflict and bridging in conjunction with real-life hands-on experience helps students achieve a deeper level of understanding of the material covered in a typical physics class.

Next, the students begin the second phase known as *Concept Invention*. Here, the students are actively searching for patterns, relationships, and ways to explain what they are observing. It is the responsibility of the teacher to act in a mentorship role at this stage, probing students just enough to keep them in a state of disequilibrium, yet guiding them ever closer to the correct mental model for the situation. An alternate role to creating disequilibrium for the teacher, is to instead initiate a bridging activity wherein

they take that which the student already knows, and find meaningful ways to guide them toward a new concept or idea. Since cognitive conflict or “disequilibrium” can have a humbling effect on a student, finding ways to focus on what they know should be used in conjunction with finding ways to put them face to face with their misconceptions so as to assist in maintaining both their confidence and their morale.

In an article published in the *Journal of Elementary Science Education* supporting the Learning Cycle model in science education, Marek (2008), explains that this model entails a very difficult role for teachers to play. We are so used to being the knowledge authority that many of us find it challenging to act as a coach on the sidelines assisting our students in their concept formation rather than just giving them the whole story ourselves. In a subsequent article within the same journal, Lawson (2008) takes a similar stance to Marek in full support of the Learning Cycle model. He also comments on the importance of teaching students reasoning skills. He states that in many science classrooms, procedural knowledge (learning how to work through a problem or formulate a concept *on your own*) is cast aside in favor of declarative knowledge (the teacher filling in all of the gaps for the student and *not* requiring them to figure anything out *for themselves*). This denies students the opportunity to develop their own powers of reasoning because whenever a situation of disequilibrium occurs, the teacher “fixes it” for the student. Therefore during the concept formation phase of the Learning Cycle, it is essential that the teacher allow students to go through the process of developing their own patterns of reasoning. Redish (2002) reminds us that we as physics teachers were probably pretty good physics students at one time. During that time, we always tried to

give the most complete and thorough answer to the teacher when called upon to do so. Now that we are in the role of physics teacher, we have to consciously break that habit of wanting to give the best answer when it is our students who are asking us the questions. We have to answer them in a way that allows them to build their mental model, and Redish concedes that this is not an easy transition for a physics teacher to make.

The third and final phase of the Learning Cycle is referred to as *Expansion*. Here, the student has the opportunity to apply their newly learned concept in different situations. This is not a place for a new or unfamiliar concept to be developed, rather it is a place for the concept being addressed to be applied in a different setting (Marek, 2008). Lawson (1988) breaks this phase down into two distinct parts: the recognition of a pattern and the ability to generalize that pattern to a variety of contexts, and the incorporation of a term or definition to describe that pattern. He tells us that a person can see the pattern or know the term, but does not have the concept until he possesses both. In other words, teachers can introduce new terms to the students, but the students must recognize the patterns for themselves. The introduction of the term immediately after the discovery of the pattern or relationship is what Lawson believes allows for concept acquisition. When this occurs, the student can then apply the new concept in other situations and contexts.

The purpose of utilizing the Learning Cycle is to have the students experience something directly to begin the process of assimilation. They then try to reason out and explain what is occurring. This process often forces them into a state of cognitive conflict or disequilibrium. As they sort out the conflict, or as the teacher carefully builds bridges between what the student knows and the new concept to be learned, they can then

make connections to other situations or contexts. This expansion phase is also called *application* or *elaboration* of the newly formed concept (Marek, 2008).

In addition to the Learning Cycle approach, an example of a teaching strategy utilizing a constructivist framework is the “Five E” model developed by Rodger Bybee. In his model, the teacher first finds a way to “hook the students” or arouse their curiosity. From a constructivist standpoint, this could mean engaging them in a hands-on activity hence the first “E” stands for Engagement (Bybee, 2002).

Then, the students are allowed to *explore* (the second “E”) with the materials. The teacher serves as a guide, helping the students formulate their own interpretations of the phenomena they are observing. The teacher then leads the students to a concrete *explanation* of the phenomena they observed. The teacher does not give the answer, rather, the teacher allows the student to give the answer through a series of carefully planned questions. This is where Lawson believes the student can then be said to have acquired the concept. Next, the concept is applied in a different context, that is, the teacher guides the students to *elaborate* on what it is they learned and show how it can be applied in other settings. Finally, throughout the process, the teacher should constantly be *evaluating* the quality of the lesson. It can be seen that following the “Five E” principle places the student squarely in the center of formulating their own reasoning patterns through direct experience, while the teacher serves as a patient guide who does not give answers, but rather asks the right questions. This is the essence of constructivism in that learners are actively constructing their own knowledge through

direct experience. This is also similar to other learner-centered inquiry approaches in that questions are posed, and the students carry out investigations to answer those questions.

Throughout this literature review, we will examine several methods of teaching physics. As we look at each of them, try to see evidence of the Learning Cycle framework embedded within them. The Learning Cycle embodies the essence of constructivist pedagogy. Other methods we will soon encounter, and the programs that utilize them, are often variations of this method of instruction.

Connections to the Literature

It is true that teaching physics in this fashion takes more time, and therefore allows for the coverage of less material. However, it is also true that the material that is covered in this fashion is more likely to be internalized by the student. There is a great deal of literature that exists on the benefits of teaching science using a constructivist approach. Constructivist frameworks insist that learners construct meaning for themselves, that is, they are not passive receivers of information (Bodner, 1986).

Evidence that Constructivist Teaching Increases Student Outcomes

McDermott, Shaffer, & Constantinou (2000), conducted a study to determine the long term benefits for students being taught physics by inquiry as opposed to more traditional methods. The context of their study was the concept of electric circuits, and their students were teachers being exposed to this material in a guided inquiry format, which embraces our criteria for a constructivist model of teaching (see p.31 for a detailed explanation of the Physics by Inquiry methodology). To prepare teachers to teach

electric circuits by inquiry, they walk them through a step-by-step process of constructing a qualitative model that they can use to predict and explain the behavior of simple circuits that consist of batteries and bulbs. There are no numbers or mathematical formulas.

Qualitative reasoning is sufficient. Specific difficulties that have been identified through research (common misconceptions) are addressed during the development of the model as they arise.

They go on to state that though many of the teachers in their pre-service and in-service courses have had considerably less preparation in physics than those in the standard introductory courses, their performance on qualitative questions has been consistently better. In fact in this study, two groups of prospective elementary school teachers were tested. One group had taken the course in the manner just explained, while the other group had taken a course on similar material, but it was taught in a more traditional, teacher centered format. The instructors for each course were very familiar with the material being presented. The first group was further divided into two groups; one group had just completed the course, and the other had completed it the previous year. The researchers found that the two groups taught by the guided inquiry format had mean scores above 80% on both the free response test, and the multiple-choice test (a value that the researchers defined as a high rate of retention). The results for the new students were nearly indistinguishable from those who had taken the course the previous year. The group in the more traditional course scored about 40% on the multiple-choice test, and only 20% on the free response test. These numbers seem to indicate that using a guided inquiry approach leads to gains that are both substantial and sustained.

Oberem and Jaisen (2004) studied the conceptual gains of middle and high school teachers being trained in inquiry-based science methods (the same Physics by Inquiry curriculum mentioned in the previous study) over a three-year period, and discovered the gains were both substantial and sustained. They mention that on the pretests, between 40 percent and 67 percent of the participants scored less than 50%. This number decreased considerably on the posttests. For every topic covered, the posttest results were dramatically higher than the pretest results indicating an increase in conceptual understanding. The increases in average scores for every topic covered were significant at the 99% confidence level from a paired samples t-test. The researchers interpreted their data to mean that the conceptual understanding of individual participants had improved considerably by the end of the three-week course, and had done so in every topic presented. The researchers believe that the guided inquiry-oriented nature of the curriculum and the way it was used in their course played a key role in the outcomes they measured, and comment that this has been confirmed in other studies as well (Oberem & Jaisen, 2004).

These researchers tested their students again three years later, and found that the conceptual gains persisted. This is consistent with the previously mentioned study, as well as a longitudinal study conducted by Francis et al (1998) where they found the gains “did not decrease significantly as many as four years after the original course” (Oberem & Jaisen, 2004, p.21).

In a large study, which began in 1992, Richard Hake, a physics professor at the University of Indiana began gathering pre and post-test data from a total of 62 different

physics classes and a total of 6542 students. The purpose of the study was to measure the conceptual gains attained by the students using the Force Concept Inventory, and the Mechanics Baseline test. He wanted to answer the question “Can the classroom use of IE [Interactive Engagement] methods increase the effectiveness of introductory mechanics courses well beyond that attained by traditional schools” (Hake, 1998, p.65). Hake broke the 62 courses into two types, “Interactive Engagement” courses, and “Traditional” courses. Hake (1998, p.65) defined Interactive Engagement methods as those “designed at least in part to promote conceptual understanding through interactive engagement of students in heads on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors.” He also noted that the methods used in the IE courses were heavily influenced by physics education research and cognitive science.

In order for a course to be considered IE, collaborative peer instruction in the form of “cognitive apprenticeship” had to be taking place (Hake, 2001). Cognitive apprenticeship recognizes the existence and power of student preconceptions, the need for a "story line" to provide students with a conceptual framework for restructuring their preconceptions, and the need to teach explicitly a problem-solving heuristic (Heller, Heller & Hsu, (n.d.)). Brown, Collins, and Duguid (1989), define cognitive apprenticeship as an adaptation of traditional apprenticeship methods for teaching people to become experts in carrying out a complex physical task. They remind us that traditional apprentices are not segregated in special learning environments -- they are immersed in a "culture of expert practice." Cognitive apprenticeship involves adapting

traditional apprenticeship methods for teaching people to become better problem solvers and higher order thinkers.

Brown et al (1989) suggest that courses taught using cognitive apprenticeship begin with a task embedded in a familiar activity. This allows the students to tap into their own prior knowledge and begin the process of assimilation. During this process, the students discover that there may be more than one correct way to answer a particular question, and one way is not necessarily superior to another way in all circumstances. While the students are discovering multiple paths to explain the concept being studied, they are actively generating their own mental model, while immersed in the problem-solving culture of the situation. Brown et al (1989) also point out that when learning occurs in this fashion, the students become enculturated, acquire some of the tools specific to that culture including vocabulary, and begin to reflect on their own construction of the knowledge with others who are actively engaged in the same process. This helps them as they move from assimilation and disequilibrium toward the desired stages of accommodation and organization.

Sometimes students with more training serve as mentors to assist newer students in learning how to think more deeply about the problems presented. The mentors assist the students in setting the context, teasing out the relevant information from a given problem, and choosing the best problem solving strategy. As the students become more adept at seeing the big picture, the role of the mentor decreases, in a process called fading (Heller, Heller, & Hsu, n.d.).

During the process, the instructor models the desired behavior in the context of problem solving during a lecture. She explains every step along the way including her thought processes, plans of attack for solving the problem, decisions as to what to pay attention to and what to ignore. Later, the students attempt to solve similar problems in the presence of a trained teacher assistant. The assistant also models the desired behavior as they work with the student. Eventually, the student learns the problem solving process, and the assistant is needed less and less. The same modeling sequence occurs in the laboratory section of the coursework. Hake (2001) notes that in each of the 48 IE courses, teaching strategies that embrace Piaget's stages (assimilation, disequilibrium, accommodation, and organization), and Vygotsky's belief that all learning is social in nature and cannot occur in isolation (we will discuss this point further when we discuss our fifth principle, the Social Learning Principle) had to be present. If they were not, the courses were then categorized as "Traditional" courses.

He defined Traditional methods as "relying primarily on passive- student lectures, recipe labs, and algorithmic-problem exams (Hake, 1998, p.65)." He also disaggregated the data into high school courses, college courses, and university courses.

What he found was that the students in the IE courses attained a nearly two standard-deviation difference in normalized gains on the post tests, and this seemed to hold true for all three age levels of students (Hake, 1998). A very detailed explanation of how the gains were calculated can be found in both Hake, 1998, and Hake, 2001. The point I am trying to make is that this large scale study provides additional evidence that using teaching methodologies consistent with our definition of constructivism, born from

research in both physics education and cognitive science, promotes a higher level of understanding in high school and college level physics students.

Qualitative data, often in the form of classroom observations and/or student interviews also provide evidence of the affective gains experienced by students taught with constructivist methods, although seeing direct evidence of true conceptual gains with this method is much more difficult, if not impossible.

In a qualitative study to determine whether the processes of assimilation, disequilibrium, accommodation and organization were actually part of the process of learning physics, Renner et al (1986) observed and interviewed students from three high school physics classes, each taught by the same teacher. They used interviews and a qualitative framework to see if these processes were in fact present. They made this decision because they felt that a quantitative instrument would leave out key elements they were looking for. This study was not looking for conceptual gains. Its purpose was to look for evidence of Piaget's processes being present during instruction. What they discovered was that:

...the exploration phase of the learning cycle provides experiences leading to assimilation and disequilibrium. The conceptual invention phase leads to accommodation and the expansion of the idea phase leads to organization. The learning cycle curriculum organization plan and teaching procedure, therefore, leads students to construct their own knowledge. (Renner et al, 1986, p.633)

Through direct questioning, these researchers found that each phase of the Learning Cycle had to be present, and that the curriculum made the students most comfortable when it moved them through the phases in the correct order. Though there was no quantitative data collected in this study, there was evidence of a qualitative nature that

suggested when instruction is aligned so students *do* follow the Learning Cycle, they do actively construct their own knowledge, a cornerstone of the constructivist teaching philosophy.

Crawford (2000) spent one year examining both the beliefs and practices of a high school biology teacher who had developed and sustained a successful inquiry based program utilizing constructivist principles. She mentions early on that she felt real learning was occurring in this setting:

As soon as I entered the classroom I was struck by the intense involvement of the students. Although no bell had rung, the twenty high school ecology students were already involved in their work... Every student appeared interested and engaged in various tasks: recording observations in notebooks; discussing their observations with other students; and retrieving materials from a back office area store-room. Jake, the teacher, moved quickly in and out of the office area, responding to different students' comments and questions. As an invited guest I moved from one pair of students to the next, inquiring about their work. Students appeared eager to talk about their projects. The students informed me that the focus of these various projects consisted of trying to create the right environmental conditions to support and maintain a female and male of a selected species. Evidence of success would be reproduction of the pair. The study organisms included native fish from local streams, praying mantises, Australian walking sticks, and slugs. Two boys were carefully placing several large insects into an aquarium. They told me these were leaf-eating insects from Australia. When I questioned if the insects could survive winters in the northwest, one of the boys quickly found some books and began to search for the answer. The teacher signaled the official start of class with his words, 'Have a seat, please. We've got to get going-to get some work done.' At the end of class the boy working with the Australian walking sticks came over to my table, bringing a resource book. Remembering my earlier question, the student told me his source indicated that the insects probably could not survive the northwest winters. (p.916)

Though the researcher did not go into detail about quantitative conceptual gains achieved by these students, it was obvious by her description of the classroom atmosphere that this

was not a traditional science class. We will see in the next section on implementation of constructivist programs that there were actually several projects occurring in addition to those just mentioned. Students were required to identify a problem, formulate a plan to gather data, analyze that data, and prepare comprehensive final reports with respect to that data. Though there were no numbers in this study, the enthusiasm and engagement of the students in their various projects came across loud and clear.

Each of these studies shows students benefiting on some level by the constructivist method of instruction. When quantitative data are the focus of the study, pre-test/post-test methodologies appear to be the predominant method used to check for student conceptual gains. These types of studies are rare in the physics education literature. Qualitative studies more often focus on how the student feels about the learning environment, or provide detailed explanations of life in the classroom, but often do not mention measurable student conceptual gains.

Evidence Regarding Implementation of Constructivist Approaches in the Classroom:

Throughout the Physics by Inquiry curriculum, discussed in detail on page 31, there are numerous “checkpoints” along the way where students must explain their reasoning to the instructor before continuing on in the lesson (McDermott, Shaffer, & Rosenquist, 1996). With constructivist approaches, the reasoning used to arrive at an answer often becomes more important than the answer itself. It is the responsibility of the instructor to act as a mentor and guide, not to fill in knowledge gaps for the student. Arts (2008), a physics professor at the University of Indiana, discovered that

implementing this program is not easy when he conducted a study in which he adapted one of his undergraduate physics courses toward a more learner-centered method of instruction. He mentioned both the difficulty and expense of using a purely lab-based method of delivery. He also noted that keeping students on task in small groups as the teacher travels from group to group could pose a challenge in some settings, particularly middle or high school. Since the students spend a great deal of time talking among themselves in groups and the teacher moves from group to group in the process, the atmosphere of the classroom is quite different than a more traditional lecture centered environment. Because of this, someone unfamiliar with the process, such as a parent or an administrator, may come to the conclusion that no real learning is occurring because there is no authority figure lecturing to the students.

On a practical level, the inquiry method is more demanding of teacher resources of time, energy and expertise. Consequently, student driven questions may be beyond the knowledge base of the teacher, and some teachers may feel uncomfortable when they are forced off their scripts (Arts, 2008). The teacher may also fear losing control of the classroom to student-oriented activities or may feel insecure with innovation or the use of new, and unfamiliar technologies. Finally, the increasing pressure placed upon teachers to prepare students for state tests hinders a teaching method like Physics by Inquiry. It takes a great deal of time to explore new concepts in this fashion, so less material is covered in a guided inquiry course. Modeling, another technique based strongly in constructivism as we have defined it faces similar challenges, because it has similar goals.

In the Renner et.al study, evidence for the importance of structuring curriculum to facilitate each of Piaget's processes in the proper sequence became evident through student responses during interviews. For example, when a student is asked about his preference of receiving new information, via lecture or via direct laboratory experience, the student responds by saying:

...I feel the lab procedure helps a lot because you can observe something happening, while if you are told, you have to imagine it, and a lot of people's images will be different. I prefer going to the laboratory because it is easier for me to understand something once I see it. Then I can put it in my own terms as other people are talking about it. (Renner et al, 1986, p.623)

Technically speaking, this student is saying he can accommodate to the concept if it is first assimilated through exploration. This emphasizes the importance of assimilation before accommodation for this particular student.

Another student comments on the explanation process that occurs after a laboratory exercise has been conducted and the terminology has been introduced "...I think that (the chalkboard work and the discussion) helps reinforce because sometimes you don't get what you are supposed to when you are doing it (the exploration) and when you come back and someone explains it (invents the concept), it reinforces it in your mind" (Renner et al, 1986, p.630). One other student adds that she only "sort of" understands the concept, even after the exploration and the discussion stages. She tells the researchers that things do not usually "come together" for her until she writes her summary sheet and begins to organize her ideas. It is at that point that things usually end up making sense to her. So for these students, the process of concept invention

(assimilation) leads into the process of organization wherein the concept begins to make sense.

This study shows us the time, effort, and expertise required of the teacher to design and sequence the curriculum to allow for Piaget's four processes to occur. This could pose logistical problems, especially if the teacher has to share a classroom or materials with other teachers. It may not be possible for the teacher to effectively create a situation wherein the four processes can occur for their students, and this could result in student learning being negatively affected. The Crawford study was an in depth case study of a single Biology teacher and the methods of instruction he used to reach his students. The teacher "Jake" went to great lengths to build connections with the community and center projects and topics of discussion in his class around the local resources available to him. For example, one of his projects was to spend a whole day in the field collecting data at the Kiger Island Slough. This was a project that he had been running for two years, and this would be the first year of data collection after a flood had hit the area, and the Fish and Wildlife people were very interested in what the students might discover. This classroom environment was tied to constructivism in several key ways. First, the teacher utilized real-life problems and local resources to engage the students. Second, the students gathered real data and often had to "grapple with" the results they obtained (they were put into a state of disequilibrium). And third, as the students made sense of their data, they were discovering patterns and relationships, often combining several different types of data to form a more complete picture of the situation in question, and during this process, they worked together, with the teacher serving as a

mentor to offer assistance and guidance when needed. His method of engaging the students in real-life problem solving seemed to mesh well with the constructivist viewpoint.

In order for Jake to do this, Crawford documented *ten* distinct roles she observed Jake play during the study. She saw him in the role of *motivator*, where he kept the enthusiasm high and let the students know that he believed in them. She saw him as a *diagnostician* in which he actively listened to student responses to determine the student's level of understanding. He was also a *guide* in helping the students develop strategies to address the problems they encountered. She saw him as an *innovator* in that he went outside the box in tailoring his curriculum to fit best with his local resources. He played the role of *experimenter* as he tried out new and innovative projects to keep the students interested. He was a *researcher* as well, as he often asked his students for feedback about his own teaching and how he could improve upon it. He also *modeled* the behaviors he wanted his students to assimilate. His attention to detail and questioning every step of the processes involved gave students an effective model for thinking scientifically. He also served as a *mentor* for his aspiring young scientists. Finally, he was a *collaborator* in that he was in constant contact with his students as they exchanged ideas with one another, and he was a *learner* every step of the way as well.

Crawford (2000) concedes that teaching in this fashion takes a great deal of effort and expertise. She also notes "An important theme in Jake's classroom involved the authentic nature of the students' work. The authenticity of the work was reflected by the students' persistence in working up the data and their beliefs that their work was

important” (p. 933). The depth and variety of the projects occurring in this classroom required a tremendous amount of planning, logistics, and cooperation from many people in the community. This teacher had the drive, the expertise, and the situation to bring all of these elements together into a coherent whole, but this may not be a reality for many K-12 teachers.

It seems that the familiar culprits of reforming education rise to the forefront when we look at implementing constructivism as we have defined it into our science curriculum. Time, money, support from administration and/or the community, and the level of expertise that the instructor must have not only within their subject area, but also expertise in teaching. Finding a teacher who possesses these qualities and a district willing to utilize these qualities to the fullest is not an easy task.

Methods for Investigating Constructivist Approaches

At the University of Washington, the Physics Education Research group began conducting systematic investigations of student conceptual understandings of various topics in physics in the early 1980's. They created situations in which the students involved in their studies were forced to come face to face with their common misconceptions. Some of their earlier studies included assessing student conceptual understanding of velocity (Trowbridge & McDermott, 1980), and acceleration (Trowbridge & McDermott, 1981). In each of these studies, they were interested in determining “the degree to which an individual successfully applies [the concept being studied] to the interpretation of simple motions of real objects” (Trowbridge & McDermott, 1980, p.1020).

They would have the students observe the motion of steel balls rolling through U shaped aluminum tracks under various circumstances, and they would interview the students to determine their level of understanding both at the beginning of the course, and again at the end. They call this process an “individual demonstration interview”, and state that it resembles the “clinical interview” pioneered by Piaget (Trowbridge & McDermott, 1980). In each interview, the student is confronted with a physical situation and asked to respond to a specified sequence of questions. Each interview lasts about 20 minutes, and is audio taped. The tapes are then transcribed and analyzed. This is done many times. In fact, in a single study in which they were investigating student understanding of velocity, over 300 such interviews took place.

When the tapes were analyzed and themes of misconceptions began to emerge, they began to create written questions to be used on examinations that specifically targeted the misconception to probe further. They were then able to create a scoring rubric to assign a quantitative value to the responses given by the students. The rubric used is listed below.

Score	Speed Comparison Task 1 Criteria	Score	Speed Comparison Task 2 Criteria
0	Student demonstrates no adequate procedure for deciding when balls have the same speed. After at least three trials, student persistently identifies passing points, or claims that speeds are never the same, or cannot decide.	0	Student demonstrates no adequate procedure for deciding when balls have the same speed. After at least three trials, student persistently claims that speeds are never the same, or cannot decide.
1	Student initially identifies one or more passing points or cannot decide, but after successive trials, identifies a region or a time at which speeds are similar.	1	Student initially claims that speeds are never the same, but after subsequent trials, revises this judgment and identifies a region or a time at which speeds are similar.
2	Student identifies similar speeds on first or second trial without confusing speed and position.	2	Student identifies similar speeds on first or second trial without confusing speed and position.

Figure 1. Scoring rubric for student responses.
Adapted from Trowbridge & McDermott (1980, p.1025).

As the data were analyzed, it was discovered that many of the students were able to solve algebraic problems involving velocity, and were also able to give the proper definition, but upon further investigation, they were not able to correctly apply the principle when confronted with a real world situation (Trowbridge & McDermott, 1980). This certainly has strong implications for instruction in that instructors must be aware of the fact that being able to recite a definition and solve an algebraic problem is not necessarily strong evidence of true conceptual understanding.

Based on their results, these researchers believed that some form of active intervention was necessary for overcoming confusion between related but different concepts. They discovered in courses where students were not forced to directly confront their misconceptions, but were instead encouraged to use pre-packaged formulas and memorize definitions, there was little conceptual gain measured between the pre and post-test interview scores. However, in courses where the students were forced to deal with their misconceptions, to talk through them and try to make sense of conflicting information, the gains were much higher. In the latter courses, the laboratory exercises were specifically designed to address conceptual difficulties as opposed to merely taking data and verifying a known principle. This leads us back once again to Piaget's processes. The students who begin the process by observing a real world phenomenon that often conflicts with what they expect to observe begin the processes of assimilation and disequilibrium. They then begin the process of accommodation as they reason through their observations and confront their present mental models, which are often insufficient to explain what they are observing. Finally, they organize the new

information as they bridge it to what they already knew which was correct, and expand their new mental model as they apply it in other contexts.

In fact, Trowbridge & McDermott (1980) state this specifically when they say “It has been our observation that for some students the acquisition of physical concepts seems to depend strongly upon the establishment of satisfactory connections between these new concepts and the protoconcepts [Ideas about physical phenomena that contain kernels of truth] with which the student is already familiar” (p.1028). They also mention that this method of accommodation is even more critical for academically disadvantaged students. The data they have acquired from this early study, and many subsequent studies on other topics covered in physics, suggests that using a constructivist method of introducing physical concepts may, in fact, assist more students, particularly academically disadvantaged students, toward achieving a deeper level of understanding. As the data has unfolded over the years for the University of Washington Physics Education Research group, they have utilized it to create a curriculum for teaching physics called Physics by Inquiry, which as we have seen from previously mentioned studies, has demonstrated success in creating both significant and sustained conceptual gains in the students who participate in it. The program in its present form will be discussed on page 31.

In the fall of 1983, David Hestenes and Ibrahim Halloun conducted a pedagogical experiment to determine whether a *model-centered* approach to the teaching of physics could create significant conceptual change in first year college students at Arizona State University. This early experiment focused on problem solving techniques utilizing what

Halloun and Hestenes (1987) called paradigm problems. Paradigm problems are carefully chosen so that they specifically target common student misconceptions, and they are structured so that students must use all of the modeling techniques being presented in the course while solving them. The technique begins with the instructor asking students to identify all relevant information, while he writes this information on the board. A classroom discussion then ensues wherein the students attempt to separate the relevant from the irrelevant information given in the previous step. Students are encouraged to defend, justify their choices for which information they feel is relevant, and which is not. When consensus is reached, the instructor then asks the students to describe problem solving plans and strategies. During this process, they are again asked to explain, defend, and justify their lines of reasoning. As conflicting points of view are worked out, and consensus is reached, the instructor then models the appropriate steps toward solving the problem.

The Arizona State experiment broke the students into four groups, a control group (CG), and three training groups (TG1, TG2, and TG3). The control group received physics instruction that did not utilize the modeling technique or paradigm problems in any way whatsoever. Their instructor solved problems out of the textbook in the same fashion that had been used in previous years. TG1, 2, and 3 received instruction wherein extra time was specifically devoted to model construction, and translation of data on a single problem maps to graphs, to diagrams, and to equations. Time was also devoted to explaining the rationale for each technique used, and the misconceptions that often arise in these problems. These primitive first steps laid the groundwork for what was to

become the Modeling physics program that is still in use today. The control group participated in weekly recitation sessions taught by experienced graduate teaching assistants, although theirs were completely independent of the treatment group's recitation sessions. TG1 had a similar format for their recitation sessions. The format for the TG2 and TG3 recitation sessions revolved around the paradigm problems mentioned previously, and TG3's session was an hour longer to take full advantage of the process. The researchers were trying to determine if taking the time to incorporate a systematic discussion of modeling techniques into class lectures and using these methods during recitation sessions to solve paradigm problems could boost student achievement (Halloun & Hestenes, 1987). They used pre and post-test data on the Mechanics Diagnostic Test (MDT, which eventually evolved into the Force Concept Inventory) to measure conceptual gains.

They discovered that the gains experienced by the control group were similar to other groups of students who had taken physics before them. They also discovered that each of the treatment groups had significantly higher gains than did the control group. In addition, they found that TG2 and TG3 were higher than TG1, with TG3 being the highest of all. They noted that the TG3 group initially started out with the highest number of lower-competence students, and their gains actually exceeded the gains experienced by the highly competent students in the traditional course. They mention that the extra hour of recitation time may have been a factor, but they also tell us that their experience teaching physics in the traditional fashion through the years has shown them many times that the extra hour combined with traditional teaching methods does not

result in significant conceptual gains experienced by those students (Halloun & Hestenes, 1987). They also tell us their results are similar to those in a study conducted by Reif and Heller (1984) that was very similar in nature. In conclusion, the researchers found early evidence for the success of using the modeling approach in the classroom. The program eventually evolved into using the laboratory experiment to gather data as a source for the model construction process, but early on the context was problem solving wherein the student would confront a misconception and reason their way toward a correct solution in a social setting with the instructor serving as a guide as the student constructed their own mental framework for the situation being studied. Modeling in its present form is discussed on page 35, because like *Physics by Inquiry*, it also embraces our definition of a constructivist classroom.

The research indicates that assessment in constructivist classrooms can take on many forms. Observing student behaviors, listening to their reasoning, and evaluating their models are methods that work well during the actual lesson. Traditional homework and tests can also be a part of the process, and research-based tests such as the Force Concept Inventory (FCI) and the Mechanics Baseline Test (MB) can be used to assess student progress throughout a course, and can be compared to larger data sets as well. Both Redish (2002) and Hake (1998) concede that more work needs to be done to create more instruments to measure student gains in conceptual understanding, and that the present instruments could be improved upon. This certainly could be a topic of future research.

The following criteria for constructivist teaching were drawn from the literature on constructivism introduced above:

Criteria for Evidence of Constructivist Teaching

1. The teacher provides some form of engagement to arouse the curiosity of the students.
2. The students explore; that is, they gather data and make observations before the introduction of formal terminology.
3. Students are often placed in a state of “disequilibrium.” What they are observing contradicts some aspect of their pre-established mental model.
4. The teacher values student input, and uses correct aspects of their pre-established mental models as starting points to build bridges to new material.
5. Students search for patterns or relationships in their data or observations.
6. Students explain what they are observing or discovering in their own words.
7. Teacher acts as a mentor while students are exploring and searching for patterns or relationships. Teacher does not “fill in the gaps” for the students at this stage.
8. When patterns and/or relationships are articulated by the student, the teacher then introduces new terminology to apply to the phenomenon being observed.
9. The student applies the newly learned concept in a variety of different situations.

10. Students express their ideas to other students in class, justify and explain their point of view, and work with one another toward a common conceptual understanding of the material being presented.
11. The teacher views students as thinkers with emerging theories about the world, not as empty vessels or as blank slates.
12. Assessment of student learning is interwoven with the teaching process and occurs through teacher observation of students at work, and through various other types as well.

This is a rather lengthy list. Though each of these criteria demonstrates some aspect of constructivist teaching practices, I believe that some of them are more essential than others. For example, I believe that #7 is a pivotal behavior the teacher must display throughout the teaching process. If this item is absent, it can be argued that the course in question is not truly constructivist. As for the student behavior, I believe that 2,3,5,6,9,and 10 should all be present, particularly in a laboratory exercise for the exercise to truly be called constructivist. Perhaps one of these steps could be missed and the spirit of constructivism would still be felt to a lesser degree, but if more than one of these criteria is absent, I suspect the course is actually more traditional than constructivist. The programs that follow, meet the criteria on this list to a significant degree.

Examples of Exemplary Programs Using Constructivism

The first program to be discussed is *Physics by Inquiry*, which is a method of physics instruction wherein all of the instruction takes place in the laboratory. It was developed by the University of Washington to prepare K-12 teachers to teach physics and physical science, and is the result of more than 25 years of physics education research. The preface of the textbook used in the course suggests a constructivist approach, although the program designers do not like to be known by a single label. “*Physics by Inquiry* is a set of laboratory-based modules that provide a step-by-step introduction to physics and the physical sciences” (McDermott, et al, 1996, p. iii). Though the program describes itself as “guided inquiry”, their framework for inquiry includes all of the major features of a constructivist approach as we have defined it. Through in-depth study of simple physical systems and their interactions, students gain direct experience with the process of science. Starting from their own observations, students develop basic physical concepts, use and interpret different forms of scientific representations, and construct explanatory models with predictive capability. All the modules have been explicitly designed to develop scientific reasoning skills and to provide practice in relating scientific concepts, representations, and models to real world phenomena (McDermott et al, 1996, p.iii). I have had the opportunity to observe firsthand how the *Physics by Inquiry* method works. I was an observer in a *Physics by Inquiry* course taught at Montana State University during the summer of 2009. The students work exclusively in groups, and the teacher acts as a guide rather than as the center of attention. The students constantly ask questions of each other and of the instructor. The instructor has to be very

skilled in how he or she answers the questions posed by the students. In my observation, the instructor was consistently able to turn the question into another question that would guide the student in the right direction, but do so in a very subtle manner. Answers are never simply given by the instructor. The instructor serves as a sounding board and as a coach as the students construct their own individual frameworks for understanding the material.

The material is also designed in a context that brings common misconceptions to the surface. For example, in one of the exercises, students are asked to rank the brightness of bulbs connected to a battery in a circuit. The bulbs are arranged in such a way that misconceptions such as “current being used up” or “current is constant across a battery regardless of the arrangement of the bulbs” come to the forefront as the students progress through the activities (McDermott et al, 1996).

By presenting the material in a laboratory format, Physics by Inquiry allows the students the opportunity to explore the concept in a hands-on fashion. The lesson provides some sort of question at the beginning to start the thought process within the student. The coursework always requires the students to make a prediction *before* carrying out an experiment (McDermott et al, 1996). This will accomplish one of two things. If their predictions are correct, the model can then be used to build upon and enhance their understanding. If their prediction is incorrect, it will place them in the state of disequilibrium discussed earlier. When they reach this state (the teacher I observed called it “hitting the brick wall”), the teacher then has to listen to what the students are

saying, and guide them toward a more reasonable explanation for what it is they are observing *but not give away the answer in the process!*

The lessons are set up as “guided inquiry” in which students are guided through a sequence of activities and questions to facilitate the construction of their mental model (McDermott, Shaffer, & Constantinou, 2000). McDermott et al (1996) describe the primary emphasis of the course being on “discovering rather than memorizing, the teaching focuses on questioning rather than on telling.” They stress the importance of time for open-ended investigations, dialogues between the instructor and individual students, as well as small group discussions. They believe that a major goal of this program is to help students perceive physics not as an established body of knowledge, but rather as an active process of inquiry in which they can participate.

When several experiments have been carried out to observe a pattern or relationship, the teacher then has the students create an operational definition of the phenomenon they are exploring. The purpose of this operational definition is to give the clearest possible idea of what is meant by a term (such as mass, heat, or current). It should clearly state the steps required to arrive at a numerical value for the quantity (McDermott et al, 1996). It is at this point that new terminology can be used to describe what is being observed. When an operational definition has been created by the students to explain that “something” is flowing from the battery through the bulbs, the term “current” can then be used from that point on. The point is that the student must create the operational definition before the term can be used.

When the term is tied into the observations the student then has a model for the basic concept. That model is then stretched and tested in other situations. In other words, the model is expanded to see how it holds up in a variety of other contexts. As the students expand their models, new states of both bridging and disequilibrium arise, and the teacher continues assisting the students in expanding their ability to define the concepts.

Assessment occurs as the teacher questions the students directly, listens to group discussions, and observes group behavior in the laboratory. More formal assessment is also present in the form of graded homework and exams, but these come only after a thorough discussion of the material among the students, and between the student and the teacher.

It can be seen that the Physics by Inquiry program contains many of the elements mentioned earlier that define a constructivist teaching method. As also mentioned earlier McDermott et al (2000), and Oberem& Jaisen (2004) have found evidence of both substantial and sustained conceptual gains from students who were taught using this method.

Some drawbacks of this method are that it is difficult to implement in a class of more than about 12-15 students. The teacher I observed explained that the difficulty arises when multiple groups are in varying stages of disequilibrium and there is only one staff member there to try to work with all of them. If the staff member is not there at the right time to keep the group momentum going, it becomes easy for them to become

frustrated or wander off task. His solution is to hire assistant teachers to help him with larger classes, but this is not a viable option in most high school settings.

Another drawback is the expense. Since the entire course is laboratory based, there is a large amount of equipment and upkeep required to furnish the students with the necessary materials. This expense may be too much for some school districts to bear.

A third drawback is that a course taught in this format looks very different than a course taught in a traditional, teacher-centered format where the students are all in their seats listening to the teacher present the material. Some administrators, parents, school board members, and even students may not equate this setting to what they consider to be “real teaching.” On the surface, it looks like the teacher is wandering around from group to group and the students are “teaching themselves.” Though this is true (and desired) to some extent, an uninformed observer may see this as ineffective teaching.

Finally, to teach in this fashion requires the teacher possess a very strong knowledge base. In chapter one, we discussed the shortage of certified physics teachers in this country, and not having a deep understanding of the principles of physics would make teaching by this method very difficult. It requires teachers to relinquish some of their control of the situations in their classroom. This means that questions may arise they are not ready for, and preparing for situations such as these requires a great deal of planning and preparation on the part of the teacher.

Despite these drawbacks, the conceptual gains demonstrated both qualitatively and quantitatively in research related to Physics by Inquiry make it an attractive choice

for curriculum designers, provided they have adequate support and a highly trained teacher to work with.

The second program discussed is the Modeling Program, which was developed at Arizona State University in the mid 1980's, and became a curriculum for high school physics classes in 1990. This method of instruction was predicated on the following four beliefs:

1. Before physics instruction, students hold naïve beliefs about concepts, which are usually incompatible with accepted scientific beliefs.
2. These naïve beliefs prevent students from attaining a deeper understanding of physics.
3. "Traditional" (lecture-demonstration) physics instruction induces only a small change in students' beliefs.
4. Much greater changes in students' beliefs can be induced with instructional methods derived from educational research (Hestenes, 1996).

The course centers on the construction of models to represent physical phenomena. Hestenes, 1996) defines the term "model" as a "unit of structural knowledge used to represent observable patterns in physical phenomena" (p.7). Therefore, this program supports the belief that the primary objective of physics teaching should be to develop student-modeling skills that allow students to make sense of their own physical experience and to evaluate information from other sources. The course differs from traditional physics in that the curriculum is built around a small number of basic models. The students spend a great deal of time creating and investigating these basic models.

Hestenes refers to this process as making a model-based inference. Later in the course, they use these specific basic models to create more generalized models that can be used in a wider variety of contexts.

The process begins with a physical situation presented to the students. The students begin to understand the situation by first making, analyzing, and evaluating a model for the situation. The students are trained first to “identify the system.” This means separating out what is relevant and what can be ignored. This first step requires practice, and is often glossed over in traditional physics classes (Redish, 2002). Next, the students are to “identify the variables.” This step involves setting up an experiment to be carried out. The students identify the independent and dependent variables, decide which variables are testable, and begin formulating a plan to set up their experiment. These two steps are usually carried out in a large group format where the teacher solicits information from the students and places all ideas on the board for discussion.

The students then carry out their experiment and analyze the data. Hestenes (1996) defines this as a process of looking for patterns and/or relationships in what they are observing, and then discussing their ideas with others within their group. The students then begin a process called model validation. Here, they compare their results with other students, and see how well their model represents the system they were investigating. It should be noted that a perfect match will probably not be attainable for a variety of reasons such as the level of precision of the devices used in the experiment, and the degree to which extraneous variables can be eliminated or at least minimized.

To summarize the process, the following synopsis was adapted from Hestenes (1996, p.6). Notice the ways in which this method tie into the criteria established for evidence of constructivism.

Notice in the “how to teach” synopsis the process is quite similar to Physics by Inquiry. Central to their view is that students learn best from activities that engage them in actively constructing and using structured representations to make sense of their own experience and communicate what they have learned with others (Hestenes, 1996). The process starts out in a strict, guided inquiry fashion, but after several cycles, the students begin to see that the outcome of every investigation is a model, which must then be clearly delineated and evaluated. They begin to internalize the process, and rely less and less on guidance from the teacher. Eventually, they become able to construct their own experiments and investigations, because they have become familiar with the process. This gives them freedom in their choice of what to investigate, and how to go about constructing a model to explain the results of their investigation.

Hestenes breaks the entire cycle down into two distinct phases: development and deployment. The development phase involves constructing and evaluating a model for some physical system. This stage incorporates Piaget’s processes of assimilation, disequilibrium, and accommodation. Deployment involves applying the model to a variety of new situations in order to explain, or make predictions. In Piagetian terms, students in the deployment phase have accommodated and organized the new concept.

Modeling Method Synopsis

The Modeling Method aims to correct many weaknesses of the traditional lecture-demonstration method, including the fragmentation of knowledge, student passivity, and the persistence of naive beliefs about the physical world.

What to teach: Model-centered instructional objectives

- To engage students in understanding the physical world by **constructing and using scientific models** to describe, to explain, to predict, to design and control physical phenomena.
- To provide students with **basic conceptual tools** for modeling physical objects and processes, especially mathematical, graphical and diagrammatic representations.
- To familiarize students with a small set of basic models as the **content core** of physics.
- To develop insight into the **structure** of scientific knowledge by examining how *models* fit into *theories*.
- To show how scientific knowledge is **validated** by engaging students in *evaluating* scientific models through comparison with empirical data.
- To develop skill in all aspects of modeling as the **procedural core** of scientific knowledge.

How to teach: Student-centered instructional design

- Instruction is organized into **modeling cycles** which engage students in all phases of model development, evaluation and application in concrete situations — thus promoting an integrated understanding of modeling processes and acquisition of coordinated modeling skills.
- The teacher sets the stage for student activities, typically with a demonstration and class discussion to establish common understanding of a question to be asked of nature. Then, in small groups, students **collaborate** in planning and conducting experiments to answer or clarify the question.
- Students are required to present and justify their conclusions in oral and/or written form, including a **formulation** of models for the phenomena in question and **evaluation** of the models by comparison with data.
- Technical terms and representational tools are introduced by the teacher as they are needed to sharpen models, facilitate modeling activities and improve the quality of discourse.
- The teacher is prepared with a definite **agenda** for student progress and **guides** student Inquiry and discussion in that direction with "Socratic" questioning and remarks.
- The teacher is equipped with a **taxonomy** of typical student misconceptions to be addressed as students are induced to articulate, analyze and justify their personal beliefs.

Figure 2. Modeling method synopsis adapted from Hestenes

The drawbacks to this method of instruction are identical to those of the Physics by Inquiry method. The process takes a great deal of time and teachers are under increasing pressure from state mandated tests to “cover “a certain amount of material. Class sizes must be small enough that the teacher can address groups as they enter states of disequilibrium. The laboratory equipment is expensive, and the atmosphere of the classroom may not be desirable to administrators or others not familiar with the rationale for the format. A possible reason for this “lack of fit” from a logistical, financial, and practical standpoint, is that both Modeling and Physics by Inquiry were originally designed to be classes taught at the undergraduate level. In this setting, one is far more likely to encounter a highly qualified instructor, smaller class sizes (remember, these are non-traditional courses), and ample equipment and support in the form of laboratory or teaching assistance. These resources are typically not found at the high school level.

The third program discussed comes from the University of Maryland, and it is called “Teaching Physics with the Physics Suite.” The information concerning the Physics Suite comes from Dr. Redish and his book *Teaching Physics with the Physics Suite*. The methods described in this program are an accumulation of over 30 years of research into physics education and cognitive science. Though the actual starting date for the program in its present form is unclear, Redish comments that he devoted his career solely to physics education in 1991, so one can infer that the elements of this program started to take on their present form around that period. The Physics Suite contains a wide variety of resources that a teacher can choose from, and it appears that the targeted audiences are high schools and undergraduate physics programs. Some teachers use

many elements from this program, while others use only a few, and integrate them into their preexisting curriculum. A major strength of the Physics Suite is the ease with which it can be tailored to meet the individual needs of the teacher. The premise behind each of the Suite elements is that “what matters most in a course is what the students actually do” (Redish, 2002, p.182). What Redish means by this, is that simply giving the students hands on activities is not enough. He argues that the patterns of thought the students use as they blend hands on activities with reflection are far more important.

The Physics Suite uses a narrative text entitled *Understanding Physics*. This text is unique in that issues that typically manifest themselves as naïve conceptions are emphasized and treated with care. The text also embraces the spirit of Piaget in that discussions are motivated by making contact with a student’s personal experience before introducing terminology to describe or name the topic being studied (assimilation and disequilibrium before accommodation and organization). Redish states multiple times that the text format is such that it draws upon what students bring from their everyday experiences and uses these as points to build bridges toward a more correct scientific model. An interesting note is that the text intentionally omits chapter summaries. It is the belief of the Maryland program that “Providing an authority-validated summary in the text both robs the students of the opportunity to construct summaries for themselves and sends the covert message to trust authority instead of building their own judgment” (Redish, 2002, p.185). Clearly this viewpoint is in alignment with the constructivist paradigm as we have defined it.

The laboratory component of the Physics Suite uses lab modules that are collectively called *RealTime Physics*. Like Physics by Inquiry and Modeling, RealTime Physics uses guided inquiry to create cognitive conflict (disequilibrium) within the student. The equipment allows for rapid, high quality data acquisition so students can focus on analyzing rather than simply collecting their information. The exposure to instrumentation, live-time graphs, and kinesthetic experiments appear to have a powerful effect on intuition building. According to Redish, students who have done these experiments are much more inclined to make physical sense of velocity and acceleration than students who have done more traditional experiments. He specifically mentions Thornton and Sokoloff (1996), researchers who implemented Physics Suite lab modules, and reported data at their home institutions showing notable pre-post gains in scores on the Force and Motion Conceptual Evaluation (FCME). The FCME has some key differences from the Force Concept Inventory mentioned earlier:

In addition to the dynamical issues stressed by the FCI, this survey addresses student difficulties with kinematics, especially difficulties with representation translation between words and graphs. It is longer than the FCI, with 47 items in a multiple-choice multiple-response format that is somewhat more difficult for students to untangle than the (mostly) straightforward FCI multiple-choice items.

(Redish, 2002, p.102)

Therefore, this test serves as a tool for determining student levels of understanding on a much deeper level than a traditional algebraic-mathematical type of physics exam.

The lecture component of the Physics Suite uses Interactive Lecture Demonstrations (ILDs). These are designed to assist students in representation translation and to help them construct and strengthen their conceptual understanding

through active engagement in a large lecture environment. Students are shown a demonstration and then given the opportunity to make predictions and discuss their predictions with their neighbors before the results are collected and displayed. The demonstrations have been specifically designed to create disequilibrium, followed by social learning. These demonstrations are run on a single computer with a large screen display.

In recitation sessions, the Physics Suite uses a product called *Tutorials*. This product was developed by the same group that developed the Physics by Inquiry program at the University of Washington. According to Redish, they have a “tight, carefully guided group-learning structure similar in feel to the RealTime Physics labs or the Interactive Lecture Demonstrations. They are based on research on student difficulties and make frequent use of both cognitive conflict and bridging” (Redish, 2002, p.186).

All of these elements are put together into a product called *Workshop Physics*. This method of instruction implies a complete structural change from the traditional lecture/recitation/lab pattern of instruction. Redish (2002) explains it in greater detail:

Typically, the class is structured into three two-hour laboratory sessions in which the students use sophisticated technology to build their physics knowledge through observation and mathematical modeling. Classes move smoothly back and forth from brief lecture segments, to class discussions, to full-class demonstrations, to small-group experimenting and modeling. An integrated set of computer tools are used for data acquisition, video capture and analysis, and graphing and modeling with spreadsheets. (p.187)

Workshop Physics is extremely effective in classes of 30 or fewer however there should be a facilitator for every 15 students or so. He concedes that learning to teach physics in this more student-as-learner and student-as-creator of their own knowledge takes time to get used to, and it may take a year or two before things run smoothly. However, as we have seen, research seems to indicate that using a guided inquiry format as a vehicle for promoting measurable gains in student achievement may be a viable option for attaining this goal.

There are other accessory elements such as peer instruction, Just-in-time teaching, and Cooperative Problem Solving that also support the constructivist method of instruction.

Peer Instruction involves the teacher asking questions to create both engagement and disequilibrium among the students. The students then enter into a discussion among themselves to come up with an answer to the question. The answers are posted and the discussion continues. This supports the social aspect of constructivism in that learning must occur in a social setting.

Just in time teaching involves the students answering context-rich, carefully designed questions before a lecture; and they do this in an online format. The instructor then examines the questions and adapts the lecture to address specific student difficulties. Redish comments that this approach sends the message to the students that the instructor cares about whether the students learn, and is responding actively to their misconceptions.

Cooperative problem solving involves grouping the students heterogeneously and getting them thinking about solving complex physics problems. This reinforces the social nature of learning and allows the students to build upon the strengths of one another. This accessory to the Physics Suite is similar to the Minnesota Model for teaching students how to solve context rich problems in a group format (see Heller, Keith, & Anderson (1991) for a more detailed explanation of the Minnesota Model).

The Physics Suite is similar to Physics by Inquiry and Modeling in that it does follow the constructivist criteria if the instructor uses the materials as intended. It differs from the other programs in that instructors have more freedom to pick and choose what best suits their situation. I propose that if the instructor is highly trained in constructivist teaching methods and has a strong knowledge base, this flexibility could be seen as an advantage. However, if the instructor lacks either of these qualities, the flexibility allows them to adapt a more traditional format. Care needs to be taken in the selection, sequencing, and implementation of the many aspects of the Physics Suite. It also has the same drawbacks as the other programs of small class sizes needed (or the luxury of teaching and/or lab assistants), equipment that is unavailable in many secondary schools, and a non-traditional format that may make parents, students, and administrators uncomfortable.

These are but three programs that embrace constructivism in similar, although not identical, ways. The River Falls program that will be the context of this study also includes most elements of constructivism as we have defined it, and it will be discussed in detail in Chapter 3.

Each of the remaining four principles outlined by Redish represent aspects of constructivist teaching as defined at the outset of this chapter. A major premise of constructivism is paying attention to the importance of context in designing a learning activity. We will now examine the Context Principle.

2. The Context Principle:

Definition

Here, Redish tells us that the basic mechanism of the cognitive response is context-dependent association. He states that new information should always be presented in a context that is familiar to the student, and that the context should be established first. What the students are able to construct depends on how what we give them interacts with what they already have. In other words, the context in which the new information is presented is very important.

Elaboration

What we as physics teachers are aiming for is to create a knowledge structure within our students that will allow them to assimilate new knowledge into that which they already know. In doing so, we must always be aware of the context we use when presenting this material. Redish reminds us that we as physics instructors have built up many years of familiarity with the contexts surrounding the material we teach. We must never forget that our students do not have the benefit of all those years of exposure to the same material. Therefore, what may seem trivial and obvious to us is probably not so

crystal clear to our students. We must take the time to supply first-hand experience with the topic being studied to serve as a starting point for our students.

Allowing a concrete starting point as an introduction to a new concept also allows the teacher to manipulate the situation to clear up any confusing aspects (such as air resistance with respect to the rate of falling objects) that may have clouded previous concept formation regarding information being introduced. In this way, the teacher can control what aspects of a physical situation they choose to let their students see, and modify the context as the students become more familiar with the concept (introduce more of the “real world messiness” of the situation as the students progress in forming their mental model of the situation). As this process occurs over and over again, students will eventually be able to discriminate between what is relevant in a particular situation, and what is an extraneous distraction. This is a valuable skill for any student of science to develop.

If the context in which the new material is introduced is relevant to the lives of the students, this also increases the likelihood they will assimilate the new information into their preexisting mental models. For example, introducing the concept of acceleration within the context of a ball rolling down a hill will probably resonate with more high school students than using the example of a charged particle in a magnetic field, because the ball and the hill are concrete connections to their everyday lives, whereas the charged particle in the magnetic field would not be nearly as familiar to them.

Examples of Using the Context Principle

If you ask your students which will fall faster, a feather or a bowling ball, you get a wide variety of answers. Many students who have never taken a physics course will answer that the bowling ball will fall faster because it is heavier. The teacher can then conduct a simple experiment where a textbook and a sheet of paper are dropped simultaneously. The textbook will win the race easily. The experiment could be repeated, but this time, with the paper placed beneath the textbook. They fall at the same rate, but the students may argue that the textbook pushes the paper down and forces it to fall at the same rate. They may then suggest that the paper be placed *atop* the textbook and the experiment repeated. In this case, the paper and textbook fall to earth together. This surprises many students, because they most likely have never seen two objects fall to earth *without air resistance* being part of the context. The instructor could then have the students repeat the experiment with different objects (through their own direct experience) so that they can begin to form a working mental model that tells them that all objects do fall to earth at the same rate in the absence of air resistance. This does not mean that the problem is resolved once and for all, because as we have discussed earlier, common naïve conceptions can be very robust and resistant to change. It is also true that the research speaking specifically to the influence of context with respect to imparting lasting conceptual change is, at present, inconclusive. However, each time the student is confronted with falling objects in the absence of air resistance, the likelihood that their incorrect mental model will begin to break down in the face of direct, concrete evidence may increase (Redish, 2002; Arons, 1997). It is possible that the more exposure students

get to falling objects in a variety of different contexts; a stone being dropped from a ledge, a ball rolling off of a horizontal surface, a bullet being fired out of a gun, a satellite in orbit around the earth; and the more they see that these objects all follow the same rules (provided the satellite is not too far away from earth of course), the more disequilibrium they will feel until they accommodate the new information into their knowledge structure by altering their belief that mass has an effect on the rate at which an object falls (Redish, 2002).

From that point on, the instructor has a concrete example to refer back to as he covers various topics in the course such as projectile motion, orbital motion etc. If students get lost and begin reasoning by using their old mental model saying that heavier objects fall faster than lighter objects, the instructor can bring them back to the correct model by saying things like “Remember when we dropped the book and the paper? Remember what happened?” The concrete experience of their dropping a textbook and a piece of paper forces them to confront their original belief that the heavier object falls faster. They then have to reconstruct their belief system about the way objects fall based upon their own actual experiences. Later in the course, the concept of air resistance can be introduced to enrich the context, but by then the students are ready for more “real world messiness” because they started out seeing the phenomenon in a simplified context.

Connections to the Literature

Evidence of Student Gains in

Understanding Using the Context Principle When the term “context-based

instruction” is defined to mean “using concepts and process skills in real world contexts that are relevant to students from diverse backgrounds” (Glynn & Koballa, p.75), research conducted to assess its effectiveness at increasing student achievement is very sparse, incomplete, and suspect (Taasobshirazi & Carr, 2008).

In a paper to both review and critique existing research on context-based physics instruction and its relationship to measurable gains in student achievement in physics, Taasobshirazi et al (2008) were only able to find ten studies from which to work. They divided the studies into two groups: one group used context-based assessments in traditionally taught courses, the other used context-based instruction along with context-based assessment. They found in the four studies which comprised the first group (Rennie & Parker (1996); Park & Lee, (2004); Heller & Hollabaugh, (1992); and Enghag, (2004)), that the data on context-based assessment provided little solid support for the claim that it improves student achievement. The authors went on to say: “Only one of the two studies examining achievement (Park & Lee, 2004) had a sufficiently large sample size to perform statistical analysis, and the results were inconsistent. The work by Heller & Hollabaugh (1992) hints at the possibility of higher achievement in the form of better problem solving, but achievement needs to be directly assessed” (p.160).

In the six studies where context based instruction was also used (Kaschalk, (2002), Rayner, (2005), Benckert, (1997), Cooper, Yeo, & Zadnik, (2003), Wierstra &

Wubbels (1994), and Murphy, Lunn, & Jones, (2006)), the researchers again cite difficulty in drawing definite conclusions about context-based instruction and student achievement. Several of the studies reported increased participation and motivation, however these are not necessarily good predictors of increased levels of student achievement. In fact, this research mentions that there is a substantial body of work in motivation, which indicates that students may find an activity highly motivating, but learn little from it (e.g. Harp & Mayer, 1998). They even reference a study that suggests highly motivating activities may actually draw students' attention away from key concepts (Shiu-sing, 2005). The researchers point out that the lack of research done on this topic does not necessarily mean that student achievement is definitely not tied to context-based instruction and assessment in some fashion, it's just that there is a need for both more and better designed research studies to attempt to answer this question (Taasoobshirazi et al, 2008).

If we shift our definition of "context" to include the situated and embedded nature of learning, and the role of local culture and the use of cultural tools that mediate human action (Finkelstein, 2003), we can see evidence of context affecting student achievement. In a paper written about a special course offered at the University of Colorado designed as an experiment to specifically assess student achievement with respect to context, Finkelstein (2003) discovered measurable positive outcomes as a result of paying specific attention to context in physics teaching. His evaluations consisted of pre-and post-tests of basic concepts in electricity and magnetism, audio

taped recordings of all class sessions, students' written evaluations of the course, and students' written statements of teaching.

The results of the pre and post test gains on selected segments of the Conceptual Survey of Electricity and Magnetism, and the Electric Circuit Conceptual Assessment indicated that every student in the course demonstrated improved understanding of electricity and magnetism (Finkelstein, 2003). These instruments have undergone extensive revision and have been reviewed by over 100 college/university physics teachers (Hieggelke, 1996). The mean pre and post test scores were, respectively 54% ($\sigma = 25\%$) and 74% ($\sigma = 24\%$). The average individual student gains were 51% ($\sigma=30\%$; $N=13$; $p<.001$). He compared these results to a study by Maloney et al (2001), in which the reported gains on a similar instrument for over 5000 college and university students was 32%. The students in the Maloney et al study were taught using the traditional lecture-lab-recitation so common in most high school and college physics departments.

Beerer & Bozdin (2004), Crawford (2000), McDermott, Shaffer, & Constantinou (2000), and McDermott (1990) state that students will obtain a deeper understanding of the nature of science if they are involved in actually doing science, forming their own mental models based upon direct observations and searching for patterns and/or relationships, rather than being told about science by a teacher, text, or some other method. It is the act of experiencing a phenomenon first hand and then trying to make sense of it that research seems to indicate provides an avenue for processing at a deeper level. The experimental course designed by Finkelstein mentioned above adhered to these principles, and added the element of student-as-teacher. One of the course

requirements for Finkelstein's course was to design a lesson on a predetermined topic, and teach it to the rest of the class. Qualitative data in the form of student and instructor interviews indicated that placing the material in the context of preparing a lesson instead of the usual method of hearing a lecture, caused fundamental conceptual change in the mental models of several of the students involved in the class (Finkelstein, 2003). In other words, when physics concepts are introduced in the context of a process such as guided inquiry or interactive engagement, measurable gains of both a qualitative and quantitative nature of student understanding have been reported in the research.

Though the research specifically targeted at conceptual gains with respect to context is relatively sparse, and the very act of nailing down a precise definition of "context" is a little uncertain at the present time, there are some intriguing results emerging that suggest researchers in this field of study may be on to something. This is certainly an area that deserves more attention in the future.

Evidence Supporting why Students Attain Deeper
Levels of Understanding when Context is Considered Finkelstein (2003)

believes, as do socio-cultural researchers of student learning in anthropology, education, and psychology, that context should not be viewed as a backdrop against which student learning occurs, but instead as an integral part of student learning. He believes, as does Redish (2002) that students constantly shape, and are being shaped by the context in which their education occurs. Finkelstein sees context in terms of learning physics as a system of three nested levels; Starting from the center and working outward, he recognizes the *task*, the *situation*, and the *ideoculture*.

The task is seen as the immediate problem to be solved. What is the story line of the problem? What is the problem asking for? The situation is then defined as the participant, the task at hand, the goals and concepts of the task, the local environment, and the tools associated with the task. Finkelstein describes the situation as the “where and how” a task occurs. In a course such as physics, many situations occur over time that are unique to the individuals involved. This creates a small group culture that Fine (1987) calls an ideoculture. The ideoculture is a collection of localized norms, customs, and behaviors. For instance, one of the norms for the ideoculture of aviation is the yelling of the word “CLEAR” before starting an airplane engine. People who are not part of the aviation ideoculture may not know what is going on, but anyone with any experience around airplanes knows when they hear that word, that the rumble of an engine is sure to follow a split second later. Finkelstein (2003) views the ideoculture in a physics classroom as something that “encompasses and is constituted by the relations among situations and tasks, through their collective weaving together” (p.11).

The class researched by Finkelstein had an ideoculture that was hypersensitive to the context in which the learning was occurring. Students were strongly encouraged to reflect on their own thinking and collaborative work and group discussions were emphasized. He described the classroom as a place where it was safe not to know the answers, and challenging one’s own assumptions about his or her knowledge was encouraged. There was also a purposeful blurring of roles for the students in this class. They transitioned from learner to teacher to problem solver, and reflected on these varied experiences (contexts) constantly.

By setting up the course in this fashion, Finkelstein was able to tease out misunderstandings about a concept that a student might have in one context, which went undetected in a different context. He uses the example of a student who had already taken two or three undergraduate courses in electricity and magnetism. She was able to solve problems dealing with capacitance easily. Her ability to plug the numbers into an equation and arrive at the correct answer was satisfactory within the context of her previous experience with the material. In this course however, she was required to *teach* the concept of capacitance to her fellow students. When attempting to construct a lesson plan, she came face to face with the fact that she really had no idea what capacitance meant or how it worked, she only knew how to manipulate the equation. By changing the context of the lesson and putting her in the role of a teacher, the instructor was able to uncover a lack of understanding that had gone undetected in various other contexts. This is but one example of the importance of treating context as an interwoven aspect of the learning process.

There is other education research suggesting that taking the time to establish the context is a very important step in ensuring student understanding. In Huitt's (2003) description of information processing, and in Haury's (1993) description of inquiry-based teaching, the authors each make reference to the fact that the more interesting, and more relevant you can make an idea for the student, the more likely the information will be processed from short term to long term memory. Though there is no numerical data associated with these findings, one can reason that processing information from short-term to long-term memory is a desirable goal.

Oberem & Jaisen (2004), remind us that students unfamiliar with physics concepts draw heavily upon their personal experiences to make sense of the incoming information. Therefore, a teacher should be aware of what prior knowledge the students are bringing with them to class. This will help the teacher establish the appropriate context for the incoming students, and as Finkelstein pointed out, it can also cue the teacher as to what particular context may be best for inducing disequilibrium in a student who may appear to know a concept when in fact they do not.

Duit, Mikelskis-Seiefert, & Wodzinski (2007) tell us that educators should not restrict their efforts to merely exploring and taking students' prior concepts into account. They also believe that to enable students to build transferable knowledge, learning must occur in contexts that closely resemble their everyday life whenever possible. These relevant contexts are seen as a useful way to improve students' interest and motivation. They go on to mention that learning should include "multiple contexts" and "multiple perspectives." Redish (2002, 1994) agrees with this point, as does Arons (1997) in his comprehensive teacher-to-teacher text entitled *Teaching Introductory Physics*.

Koponen, Mantyla, & Lavonen (2004), and Stein (2001), express the need for physics teacher training programs at colleges and universities to stress the importance of setting the context of physics as a series of interconnected phenomena rather than a compartmentalized and fragmented discipline as it is often presented in high school and undergraduate programs. By presenting physics topics in the context of interconnectedness rather than as isolated bits of information, students begin to see the

big picture, and are able to link new concepts to old ones because the context of connectedness has already been established. Redish (2002) elaborates:

A major strength of the scientific worldview is its ability to describe many complex phenomena with a few simple laws and principles. Students who emphasize science as a collection of facts may fail to see the integrity of the structure, an integrity that is both convincing and useful in solving problems. The lack of a coherent view can cause students many difficulties, including a failure to notice errors in their reasoning and an inability to evaluate a recalled item through cross checks. (p. 48)

So, one major context to promote an understanding of the larger picture in the study of physics is that of interconnectedness.

Suggested Methods for Establishing Context in a Physics Lesson

Redish reminds us that the real world presents a flood of information to us each second we are alive. He notes that many introductory physics students have a great deal of difficulty separating out relevant information from distractions in a physics problem, laboratory exercise, or discussion. He proposes a method he calls “restricting the frame” in which we only consider a piece of the whole. We intentionally leave things out to avoid unnecessary distractions. This may seem contradictory to the idea of making a situation as true to life as possible for our students, but it really is not. When we introduce a new concept, we start by stripping away the distractions. As our students begin to form a working model for our “stripped down” version, we add more of the real-life elements. For example, when we discuss objects sliding down a ramp, often times we make that ramp “frictionless” when we begin the process, but after the students become comfortable with the frictionless ramp, we add the real world element of friction.

Initially, it is a distraction, but eventually, it becomes part of the real life situation to be considered (Redish, 2002). Along the way, we also model the processes we use to sift out irrelevant information; processes we often take for granted because of our years of exposure to various contexts in the field of physics. We must model these processes, because our students often do not have the contextual experience that we as instructors have. Redish strongly believes that this point is not a trivial matter.

Redish also suggests the utilization of multiple representations, such as graphs, tables, diagrams, words, and equations to present the material in a variety of contexts. This idea will be explored in greater detail when we discuss the Individuality principle, but it also serves as a method for presenting the same situation in a variety of contexts. By using multiple contexts, we can help our students organize their knowledge into mental models that will trigger appropriate responses in a wide variety of situations. Said another way;

It is not sufficient for students to “know” the relevant correct statements of physics. They also have to be able to gain access to them at the appropriate times; and they have to have methods of cross-checking and evaluating to be certain that the result they have called up is truly relevant. To do this, they need to build a coherent and consistent mental model of the subject. If we want to help our students build good models of the physics content, our cognitive model of student learning provides some guidance. The experience that outstanding teachers have reported is consistent with what we learn from researchers in cognitive and neuroscience: activities teaching thinking and reasoning have to be repeated in different contexts over a period of time. (Redish, 2002, p.49)

Arnold Arons (1983) agrees when he says that repetition is crucial in the instructional process. But repetition of the same concept in different contexts, with each cycle being more representative of the real world situation, and each cycle occurring after some time

is allowed for the students to process the new information. Both Redish and Arons agree that learning is a growth process and not a transfer. The data from cognitive science and physics education research seems to indicate that building functional scientific mental models does not occur naturally for most students. They need repetition, reflection and exposure to the material in a variety of contexts to truly assimilate, accommodate, and organize their mental models. The earlier description of the physics course developed to test whether context could be tied to gains in student achievement also supports these statements and stresses the importance of the ideoculture within the classroom as well. Learner and context cannot be treated separately in a constructivist classroom. The idea of multiple representations stretches far beyond the realm of physics. In any science discipline, or any discipline whatsoever, being able to learn and convey information in as many ways as possible is valuable.

Criteria for Demonstrating the Context Principle

1. Teacher realizes the importance of simplifying contexts at times to remove distracting information; particularly when students are first exposed to the material.
2. Teacher makes the context more realistic as understanding is elaborated.
3. Teacher trains students to recognize what is relevant and what is a distraction in a particular situation.
4. Teacher selects contexts that are familiar enough that students can easily make connections.

5. Teacher attempts to select contexts that will engage and interest the students whenever possible.
6. Teacher or curriculum immerses students in a culture of problem solving, or a culture of actually doing science.

Examples of Successful Programs Using the Context Principle

The Physics by Inquiry program starts the students out with a very basic model of the concept being taught. This approach provides a foundation that can be built upon as the students become more comfortable with the concept. In the electricity unit, the students start out with a battery, a single bulb, and a wire. As they build their mental model for current, the circuits become more complex, with some of them containing six or more bulbs arranged in both parallel and series within the same circuit. The context is simple at first, and gradually begins to resemble a real world situation.

Eventually, there is a problem that the students encounter that extends the concept beyond the laboratory. They are asked to arrange a circuit with a single bulb and two switches such that either switch can turn the bulb on or off. This is the circuit that exists on nearly every stairway in America, so that you can turn the light on or off whether you are at the top or bottom of the stairs. This is an example of taking a concept learned in the laboratory and extending it to the context of wiring a real house.

Since the entire process occurs in the laboratory, the students are constantly asking questions of themselves and the instructor. The atmosphere is very collaborative, and the context is social. By working in groups, the students are able to explain their reasoning to one another, justify and defend their own points of view, and ultimately

verify them by direct experiment. Over time, the students learn to recognize which aspects of a situation are relevant, and which aspects should be ignored. For example, if the students construct a circuit in some way, then change the arrangement somehow, they are able to discern what will change in the overall circuit, and what will remain constant. Through repeated exposure to the concept in slightly different contexts and with ever-increasing complexity, the students are able to apply their knowledge to new situations, and apply it correctly.

The Modeling program begins with a large group discussion wherein the teacher guides the students to identify the system they will be investigating. Next, they identify the variables they will be testing. In these two activities, the teacher is training the students to recognize the information that is relevant to the situation and that which can be ignored. By doing this, the teacher is also simplifying the context in which the activity will take place. By making the students aware of both the system to be examined and the variables involved, the teacher has led the students to construct a “restricted frame” in which to carry out their activity.

Throughout the process of gathering data and formulating their model to explain the behavior they are observing, the students work in small groups. Similar to Physics by Inquiry, this provides the students the opportunity to share ideas and justify or defend their interpretation of the observation. At the conclusion of the activity, the students prepare a whiteboard with various representations of their model including a graph, an equation, a diagram, and a written description of the model and its implications. They then must present their findings to the larger group, justify and defend their reasoning,

and answer questions from the group. Taking the experience from the context of a small group discussing ideas among themselves to the context of being center stage and presenting their findings takes some getting used to for some students. For many of my own high school students, constructing the model is not nearly as challenging for them as trying to explain it verbally to a large group. This idea will return when we discuss the Individuality principle.

Exposure to the materials required to create the model occurs in a laboratory setting, so the students actually generate their own data. By using the laboratory as the context in which to present the material, this program is creating a hands-on situation in which the students create their own mental model of what they are observing in real time. As mentioned earlier, research seems to indicate that authentic experiences such as these make the process of accommodation more likely to occur because it is more difficult to ignore something you see with your own eyes or create with your own hands.

Eventually, students learn the pattern of the course. Every laboratory activity results in the formation of a model to explain the observations. With each new pass through the Modeling Cycle, students become more independent and able to answer more questions for themselves. They rely less on the teacher, and more on their own mental models to complete the activities. By doing this, they also see the interconnectedness of the models. As previously mentioned, research has shown that when students are taught to view physics as a series of interconnected phenomena instead of disjointed facts, they are more likely to accommodate and organize what they have assimilated into a correctly functioning mental model of physics (Redish, 2002). The experiments become more

complex with each new cycle as well. In fact, the course is actually structured so students can design their own experiments, including investigations not necessarily part of the curriculum, once they are familiar with the process. This freedom of choice increases the chance that the context will be relevant and engaging to the student.

The Physics Suite, as mentioned in the previous section, has many resources to draw from. The text, *Understanding Physics*, was written in the belief that physics resources should be as relevant to the daily lives of our students as possible. By finding out what our students know, we can provide a context in which we can build bridges to link correct mental models to new information, or we can create cognitive conflict (disequilibrium) and have our students confront their misconceptions. The text also has a small number of “touchstone problems” which are included to emphasize the context of interconnectedness in physics. These problems are thematic in that the concepts they are showing are recurring themes in the study of physics (energy is conserved, for example).

The RealTime physics labs are similar to both Physics by Inquiry and Modeling in that they have the students working in small groups. The students gather data, and discuss ideas with one another regarding how to interpret the data and construct their models. The format is guided inquiry with both cognitive conflict and bridging being used as methods of delivery.

The Interactive Lecture Demonstrations are designed specifically within the context of student misconceptions. They are presented to a large group to stimulate disequilibrium, and facilitate social learning by opening up avenues of discussion for the

students to consider. They also work well within the context of a large classroom, so they may be an advantage to teachers with large numbers of students per class.

The Tutorials, which are used in recitation sessions, also utilize disequilibrium and bridging. The Tutorials were designed by the creators of the Physics by Inquiry program at the University of Washington.

In the hands of an experienced and highly trained physics teacher, all of these elements can be blended into what the Physics Suite refers to as *Workshop Physics*. The curriculum is specifically designed to provide exposure to physics material in a variety of contexts, and at a variety of levels. Large group lecture and discussion, small group discussion, laboratory activities, group problem solving, and computer-assisted demonstrations are all part of Workshop Physics. The Just-in-time accessory to Workshop Physics is an excellent way for a teacher to modify the context in which they will present their lesson based on real time student input. The students respond to a probing question posed by the instructor before the start of a lesson in an on-line format. Based on the responses, the instructor can create a context in which to introduce the material that will be most relevant to her students.

The three programs above are in line with the notion that the context in which the material is presented contributes to deepening students' physics understanding. Designing lessons with constructivist features, including intentionally selecting contexts for learning, is intended to increase the chances that our students will create a meaningful and permanent change in their incorrect or incomplete mental models. This conceptual change is what we will examine next.

3. The Change Principle

Definition

Redish defines change by saying “It is reasonably easy to learn something that matches or extends an existing schema, but changing a well-established schema substantially is difficult” (Redish, 2002, p.33). Said another way, if we don’t almost already know the new material, it is quite difficult to learn it.

Elaboration

By change, Redish is referring to conceptual change. In an experimental project to create a learning environment to foster deeper levels of understanding in elementary science, Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, (2001), defined conceptual change a process that requires a significant reorganization of existing knowledge structures. These knowledge structures about the physical world may begin to take shape as early as infancy, and allow us to construct what Vosniadou et. al. (2001) call intuitive knowledge. This intuitive knowledge allows us to function in the physical world, but it is often at odds with scientific knowledge. Redish (2002) notes that it should not surprise us that our students have these misconceptions. He notes that students spend their entire lives watching objects that are set into motion eventually come to rest. Therefore, the fact that many students believe that the natural state of all objects is the state of rest really is not so surprising. The intuitive knowledge that we form early in our lives, though incorrect in a scientific sense, serves us adequately as we function in our everyday world. It is because we have held onto this intuitive knowledge for our

entire lives, and because we have seen it work countless times, that we have such trouble letting go. The change principle states that changing a well-established mental model is not an easy task. In fact, numerous researchers have discovered that conceptions grounded in everyday experiences are extremely resistant to change (Redish, 2002, Vosniadou et. al. 2001, Jones, Carter, & Rua, 2000, and Driver, 1989) just to name a few.

Connections to the Literature

Evidence that Producing Conceptual Change is Difficult According to Posner et al (1982), students come into our classrooms with initial conceptions about the physical world based upon their direct experiences. Vosniadou et al (2001) warn us that students often will not see a reason to change their beliefs because they work well in their everyday lives, they seem to explain what the student observes daily, and they have functioned as such for years. They go on to say that if we really want our students to become scientifically literate, we have to persuade them to put forth the effort to reexamine their initial beliefs and explanations of physical phenomena in an environment where the results clearly connect to their daily lives. In other words, we need to relate what they are studying beyond the limited realm of the classroom and show them a wide variety of contexts in which the new belief system can function. Strike & Posner, (1992), state that four things need to happen in order to set the stage for a conceptual change to take place. First, the students must become dissatisfied with their current conception. Second, a new concept must be presented to the students in terms the students can

understand. Third, the new concept must appear initially plausible to the students, and forth, the new concept should be of benefit to the students.

Redish (2002), Vosniadou (1994), and Driver (1989), tell us that it is much easier to learn something new if it ties in closely to something we already know. Vosniadou et. al. (2001), and Driver (1989), differentiate between new information that is consistent with prior knowledge (which is usually assimilated into the knowledge structure of the student correctly with little effort), and new information that runs contrary to prior knowledge. They agree that if the new information runs contrary to the students' prior knowledge often the students will twist the new fact to fit into their existing structure. This usually results in the formation of what Vosniadou et. al. (2001) call a synthetic model, and what Redish (2002) refers to as a common naïve conception. In a five year study designed to analyze students' problems solving performance on similar problems posed in diverse representations, Meltzer (2005) indicated that "although questions [can be] nearly identical and illustrate different ways of representing the same concept, to an introductory [physics] student, they might appear very different" (p. 463). Meltzer goes on to state the importance of utilizing multiple representations and teaching the translation skills to accompany these representations if we are truly striving to achieve lasting conceptual change in the minds of our students. His study showed trends among responses to questions posed in different ways using multiple representations that followed along lines of gender, as well as along lines of which representation was used to ask the question (Meltzer, 2005). Meltzer's study provides additional evidence for the

strength of using multiple representations and taking the time necessary to teach students how to translate between these representations.

Methods for Creating Conceptual Change

Jones et al (2000), and Driver (1989) share that their research is beginning to show us that both the prior knowledge and experiences of our students figure prominently in the development of conceptual understanding. They also remind us that situating the learning in a familiar and relevant context may increase the likelihood that the concepts being explored will be internalized more deeply.

Vosniadou et al (2001) and Driver (1989), remind us that learning is not an individual endeavor but rather a social one, and as such, teachers should encourage collaboration and take students' individual differences into account. These ideas will be explored in detail when we discuss the Individuality principle and the Social Learning principle, but deserve mention at this point, because of their role in creating conceptual change in our students.

Redish (2002) discusses two methods of instruction specifically designed to create conceptual change: cognitive conflict and bridging. The cognitive conflict model is used when trying to change a robust, inappropriate generalization or relationship, and has its roots in Piaget's description of assimilation and disequilibrium. Each of the examples of exemplar programs to be discussed shortly, utilize some form of cognitive conflict in their methodology. Bridging utilizes that which students bring to the table that is correct. With bridging, the instructor utilizes what is already intact and correctly aligned as a bridge to new material and new associations.

Cognitive conflict involves forcing a student to come face to face with an inconsistency between his or her mental model, and their actual observation. The student directly observes something in a physics lesson that an incorrect schema cannot logically explain, resulting in disequilibrium. The student then enters into an active dialogue with herself, the course facilitator, and other students in the class (they begin the process of accommodation). The lesson is then presented in a variety of contexts, each time forcing the student to see the errors in her previously constructed mental model. Allowing the student to come face to face with inconsistencies in her reasoning seems to be an effective method for assisting the student in releasing very tightly held, but incorrect, mental models about physical phenomena, and the positive effects have been observed to last for several years (Oberem & Jaisen 2004, McDermott, Shaffer, & Constantinou 2000, Hestenes 2006, Francis et al 1998, and Hake 1998).

The problem with using cognitive conflict, however, is that it is rather negative in its approach. It always makes the students “see how stupid their ideas are” and having this message pounded into their heads on a daily basis can no doubt lead to anxiety about the subject matter. It can be very uncomfortable, perhaps even frightening if, every day, you are forced to confront your weaknesses. But Redish pointed out that if we could somehow start out with something the student knows that is correct, we could use that as a starting point to build a bridge to other things. He mentioned the work of John Clement (1989) wherein the physics instructor used this bridging method to help students incrementally transform their incorrect mental models into the accepted scientific model. Clement stated that the starting point for a bridge should be something that the student

knows well. He called this starting point an *anchor*. In his work, he looked for examples in which the students had very basic, but correct ideas about physical phenomena that could be built upon. He then developed a brief list of guidelines, which point out the characteristics of a good bridging lesson. Clement's guidelines as presented by Redish (2002) are presented below.

1. It should trigger with high probability a response that is in rough agreement with the results of correct physical theory.
2. It should be concrete rather than abstract.
3. The student should be internally confident of the result; that is, students should strongly believe in the reasoning by themselves and not by virtue of authority. (p.42)

Clement also pointed out in his work that the instructor must always be cognizant of the fact that what may seem like a logical anchor to us may not be the best starting point for our students. He tells us once again that the context we bring with us to our classroom is most likely quite different than the context brought by our students. He reminds us that because each student is a unique being, we will probably have to utilize several different anchor points in several different ways to reach the maximum number of students.

There is also the troubling fact that the real world sends a flood of information to us every second we are alive. There is no way for us to process every bit of new information as it arrives, so our thought processes continuously work together to separate the information into important data that needs to be considered, and irrelevant data that can be ignored or discarded. Redish points out to us that many of our physics students

have a very difficult time separating out the relevant information in a particular lecture, problem, or demonstration. What may seem obvious to us as experienced physicists as relevant and irrelevant is usually not so cut and dry for our students. He believes that helping our students develop the skill of sifting through this information and focusing only on what is essential is a very important task that we as teachers should be attending to, and that all too often, we fail to recognize this.

One way to better ensure that more of our students stand a chance to make a meaningful connection to the material we are presenting is to utilize multiple representations in our presentations. Some examples of these representations are presented in the diagram below.

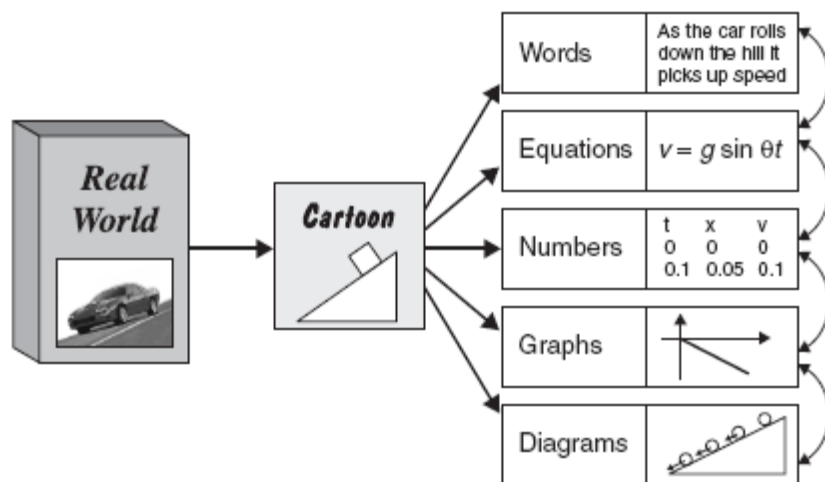


Figure 3. Some examples of representations used by physics teachers in the classroom. Adapted from Redish (2002, p.47).

Redish comments that representations such as *words*, *equations*, *tables*, *graphs*, and *diagrams*, when used in combination with one another help students utilize more of their working memory, and since each of them sets off a different thought process, there is

more of a chance of a new connection being made to the existing material the student already possesses. But we must remember that to the expert, each representation makes sense, and switching from one representation to the next is a trivial issue. The same cannot be said for our students. Often times, they are not at a level sufficient to readily translate between one representation and another. In fact, Redish mentions other studies in which they discuss the difficulties students have with representation translation (Thornton & Sokolov, 1990; Beichner, 1994). For example, he cites the familiar pattern of student reasoning when they construct a graph to solve a problem. Often the students see the graph as the solution to the problem without realizing that the graph is actually a tool meant to be used to solve a more complex problem (Redish, 2002). In other words, if students do not truly understand the purpose of the representation, chances are they are probably not going to understand the true nature of the question being asked either.

Redish summarizes what he believes all instructors in physics should be striving for. He reminds us that truly learning physics entails a great deal more than simply memorizing a bunch of equations and formal definitions. He believes that we should be striving to get our students to learn enough physics to know what the problems they are solving are about, how those problems tie into the preexisting knowledge of our students, how the course material ties directly into the real world of our students, and also how to use their knowledge effectively in solving problems. He reminds us that master physics teachers often indicate experiences in their classrooms consistent with what the fields of neuroscience and cognitive science have taught us: Activities designed to teach thinking

and reasoning have to be repeated in different contexts over a period of time. Arnold

Arons (1990) as cited in Redish (2002) elaborates:

It must be emphasized however, that REPETITION is an absolute essential feature of [effective] instruction – repetition NOT with the same exercises or in the same context but in continually altered and enriched context...Experience... must be spread out over weeks and months and must be returned to in new contexts after the germination made possible by elapsed time. Starting with only a few students being successful, each repetition or re-cycling sees an additional percentage of the class achieving success, usually leveling somewhere below 100% of the total after approximately five cycles. (p.49)

All of this leads Redish to the conclusion that learning is a growth rather than a transfer, and that real learning involves real structural changes among neural connections.

Vosniadou et. al. (2001) and Driver (1989) concur that by the time students enter elementary school, research has found that they have already constructed initial conceptual structures that in many cases differ significantly from the scientific concepts they will later be exposed to. Further, it is these initial structures upon which all future information will be added. They state that; “the process of conceptual change appears to be a gradual and complex affair during which information that comes in ... is incorporated into the existing knowledge base” (Vosnoidou, 2001, p.390). It takes repetition, reflection, and a continual meshing of new ideas into an existing framework to build a strong functional knowledge schema. This process is not a spontaneous one for most students. It is only by carrying out repeated and varied exercises that we can hope to construct this knowledge base.

In chapter 3 of his book, Redish begins to explore what he calls *the Hidden Curriculum* in physics teaching. Here, he explores some of the more underlying forces at

work in the mind of the students as they attend a physics class. Redish believes that most students do not have a true picture of what it means to “do science.” He created a list that he calls the “dead leaves model” that most students rely on as they plod their way through a science class. He states that most students tend to:

- Write down every equation or law the teacher puts on the board.
- Memorize these, along with the formulas listed at the end of the chapter.
- Do just enough homework problems to recognize which formulas should be used in which problem without really understanding why.
- Pass the exam by selecting the correct formula for the given problem (usually by the process of elimination).
- Immediately erase all information needed for one exam once it is over to make room for the next set of materials. (Redish, 2002, p.52).

To get students to move past this mental model of doing science involves exploring what Redish calls a second level of cognition. He tells us that there has been considerable research done on this second level which is sometimes called *executive function*—which describes thinking processes that manage and control other thinking processes (Anderson, 1999; Baddeley, 1998; Shallice, 1988, as cited in Redish, 2002). One of those executive functions Redish calls *expectations*. He defines expectations as those thought processes that students bring with them into our classrooms about how things are going to be run, what they should have to do to succeed, what skills are going to be needed, and how their success will be determined. He comments that expectations

can become a major obstacle to student success when the expectations of the student are vastly different than the expectations of the professor.

Two large scale studies involving general cognitive expectations of adult students are mentioned in this chapter; those of Perry (1970) as cited in Redish (2002), involving students at Harvard and Radcliffe those of Belenky (1986) as cited in Redish (2002) which focused on the views of women in various social and economic circumstances. Redish states that both studies show that the students usually started in what he calls a *binary* knowledge state. Here, the students expect everything to be right or wrong, true or false, black or white, and they expect to be told the absolute truth from authority. Then, both studies showed the students moving through a stage where they felt that nothing was true or good, and every view has an equal value. Finally, some of the students were observed to transform into a third, more highly evolved state of thinking that Redish calls *conscious constructivism*. In this third stage, the students come to the realization that nothing can be known absolutely, and that their own schemas play a role in their decision-making processes. Despite the fact that both of these studies focused on areas other than science, Redish (2002) points out that most any science teacher can attest to students evolving through these same three thought processes as they progress through their science courses.

He also brings up an interesting point about what exactly we are cultivating in our classrooms as we educate our students. Sometimes, we actually encourage behaviors that we really do not want our students to learn, and we do this without realizing it. Although research indicates that using the previously mentioned “dead leaves model” which

essentially asks students to memorize a batch of equations, solve problems with them, supply the equations in familiar in familiar situations on an exam, and then clear their minds to make room for a new set of equations is not the most effective method of creating lasting conceptual change, many physics educators appear to resort to this method. This could be because of time constraints, class sizes, or a variety of other reasons. This leads the responsible physics instructor to the conclusion that maybe just noting that the student gets the right numerical answer on a mathematical physics problem is not the best indicator as to the true level of his or her understanding of the material. The Finkelstein (2003) study, discussed in the context section also indicated direct evidence of this. Many students can tease out the correct equation by a process of elimination and manipulate the variables in order to get a satisfactory answer, but do they *really* understand *why* their answer is correct? Figuring out how to probe for these deeper levels of understanding is a major challenge for the physics instructor who truly wants his students to reach a deeper level of understanding within the subject area.

Redish also talks about the process of *metacognition*; that is, thinking about one's own thinking. When students are practicing metacognition, they are actively evaluating their ideas, checking them against personal experience, checking for consistency, deciding what is important and should be paid attention to and what is extraneous and should be ignored, keeping other options in mind, and so on. Redish has found that even his most advanced students in introductory courses rarely process the incoming information in these ways. In order to turn students into sound scientific thinkers, we must train them to think about their own thinking. The burden then falls upon us to

create a curriculum that allows our students to practice with more sophisticated forms of thinking and reasoning. As mentioned earlier, it is only through repetition and rehearsal that students become familiar enough with new material to incorporate it into their pre-existing schemas. Therefore, if we wish to develop students able to reflect upon their own thought processes, we must create an atmosphere where, in time, this becomes second nature to them. Redish tells us that by carefully guiding the students through the problem solving process and getting them to think about each step along the way the physics instructor may be able to transform the way the students think about problem solving. The early desire to charge headlong into a problem without first formulating a plan of attack and checking often for progress, may give way to a more careful approach involving planning, questioning, and thinking about the purpose of each step along the way (Redish, 2002).

Though it may seem obvious to us that the logical way to solve a problem is to plan it out first, this is not the way that most of our students think. For many of them simply diving in and racing toward a final answer is the order of the day. It no doubt takes a great deal of time and energy to teach students that planning first will actually save them a great deal of work and struggles later on, but the research seems to indicate that this is time and energy well spent.

In conclusion, creating conceptual change is a very difficult and complex task. We as instructors have to overcome the strong desire our students have to hold onto their conceptual frameworks that have served them so well their entire lives. We have to convince them that changing these belief systems is worth the time, effort, and

discomfort that it causes. Beerer & Bozdin (2004), Koponen, Mantyla, & Lavonen (2004), Oberem & Jaisen (2004), Vosnoidou (2004), Redish (2002), McDermott, Shaffer, & Constantinou, (2000), Hestenes, (2006), Hake (1998), Haury (1993) and Driver, (1989) all discuss how hands-on, real-life, active learning situations are designed to cause students to constantly reshape their mental frameworks as they are faced with information that does not mesh with their current mental models. It is only through a direct confrontation between the students' perception and reality that the barriers begin to break down. Jauhiainen et al (2002) and many others remind educators to pay special attention to areas in the physics curriculum where students commonly struggle. It is in these areas that inaccurate mental models prove to be extremely robust. Finkelstein (2003), Redish (2002), McDermott & Shaffer (1992), Shaffer & McDermott (1992) and Driver (1989) remind us that just because a student can solve a problem algebraically, does not mean that they truly understand the qualitative nature of the situation.

All of these studies (and there are many more) point to the same conclusion: Changing well-established mental models in the minds of our students is not a trivial issue. My naïve belief as a beginning teacher that I only needed to say something once and my students would get it could not have been more off the mark. Research is suggesting that a great deal of time and energy must go into searching for the best methods and the proper contexts to initiate a deep and permanent conceptual change in the way our students think about physics.

Evidence that Creating Conceptual Change

Increases Student Achievement in Physics

In addition to the quantitative studies previously discussed in both the constructivist and context sections, a study designed specifically to address the relationships between conceptual *assignments*, conceptual change *discussions* on student misconceptions, and student achievement was carried out in 18 high school physics classes in the state of Florida (Eryilmaz, 2002).

The study group consisted of six physics teachers, their 18 classes, and a total of 396 students. The researchers wanted to evaluate the effects of conceptual assignments and discussions designed to address conceptual change on both remedying student misconceptions of force and motion, as well as increasing student achievement on two diagnostic tests.

The two diagnostic tests they used were the Force Misconception Test (FMT), and the Force Achievement Test (FAT). The FMT is designed specifically to assess student *misconceptions* about force and motion, and the author indicates that wrong answers on this test often provide more information than correct answers. All of the FMT questions are conceptual. The FAT is designed specifically to assess student *achievement* in force and motion, and as such, most of the questions are quantitative in nature.

The FMT is structured so that a higher score means less student misconceptions. The FAT is structured so that a higher score means a higher level of student achievement. Both tests utilize some aspects of the aforementioned Force Concept Inventory (FCI), as well as other conceptual and quantitative questions (Eryilmaz, 2002). The FMT was found to be statistically reliable, with a Cronbach alpha of .70. The author considers this

a “moderate or relatively high reliability for a diagnostic test” (p.1004). The FAT was piloted, and then checked by a physics professor and a high school teacher for face and content validity by comparing the content of the test with the test specification. Internal reliability measures indicated a Cronbach alpha of .74 for this test, which the author indicated as a relatively high value for a diagnostic test. Students from all four experimental groups took both of these tests as a pre test, and then both as a post test 10 weeks later.

The four experimental groups were as follows:

Group 1: No conceptual change discussions; Work quantitative assignments.

Group 2: No conceptual change discussions; Work conceptual assignments.

Group 3: Conceptual change discussions; Work quantitative assignments.

Group 4: Conceptual change discussions; Work conceptual assignments.

The students in the conceptual change discussion groups participated in discussions that followed the following format. Notice familiar aspects of this format with respect to our overarching definition of constructivism. This format was taken in its entirety from Eryilmaz, 2002, p.1007.

Discussion Guidelines

1. Use the conceptual question as an exposing event that helps students expose their conceptions about a specific concept or rule.
2. Allow all students to make their own conceptions or hypotheses explicit (verbally and pictorially).
3. Ask what students believe or think about the phenomena and why they think so.
4. Write or draw students' ideas on the blackboard even if they are not correct.
5. Be neutral during the discussion. If one or some students give the correct answer, take it as another suggestion and play the devil's advocate.
6. Be patient. Give enough time to the students to think and respond to the questions.
7. Ask only descriptive questions in this part to understand what students really think about the phenomena.
8. Try to get more students involved in the discussion by asking questions of each student.
9. Assist students in stating their ideas clearly and concisely, thereby making them aware of the elements in their own preconceptions.
10. Encourage confrontation in which students debate the pros and cons of their different preconceptions and increase their awareness and understanding of the differences between their own preconceptions and those of their classmates.
11. Encourage interaction among students.

Figure 4 Continued

12. Create a discrepant event, one that creates conflict between exposed preconceptions and some observed phenomenon that students cannot explain.
13. Let students become aware of this conflict; cognitive dissonance, conceptual conflict, or disequilibrium.
14. Help students to accommodate the new ideas presented to them. The teacher does not bring students the message, but she or he makes them aware of their situation through dialogue.
15. Make a brief summary from beginning to the end of the discussion.
16. Show explicitly where oversimplification, exemplification, association, and multiple representations have happened, if any. If not, give exemplification, associations with other topics, and multiple representations for the topic.
17. Give students a feeling of progress and growth in mental power, and help them develop confidence in themselves and their abilities.

Figure 4. Discussion format for conceptual change format for students from Eryilmaz (2002, p.1007).

The teachers not assigned to the conceptual discussion groups were not given these guidelines.

The results indicated that the conceptual change discussion produced statistically significant gains in both reducing the number of student misconceptions and increasing student achievement. However, the statistical analysis suggests that the dependent variable “student misconceptions” influenced the results on the other independent variable “student achievement.” For a detailed breakdown of the statistical analysis of

this study, please refer to Eryilmaz, 2002, pp. 1008-1011. The researcher was confident in concluding that “weak evidence was provided by the study that conceptual assignments and the combined effect of conceptual assignments and conceptual change discussions were effective means of reducing the misconceptions the students held, and significantly improved students’ physics achievement in force and motion” (p.1011-1012). The researcher also pointed out that when the conceptual assignments were used without the discussions, the effect size of their gains was actually *less* than those of the control group (no conceptual assignments and no conceptual discussions). He speculates that because the conceptual assignments dealt with daily-life phenomena, they tended to *reinforce* student misconceptions since there was no discussion format for the students to address their misconceptions. This suggests that simply using constructivist assignments with our students and expecting them to show measurable achievement may be naive. As has been mentioned several times previously, time for discussion and reflection in a social context is a critical ingredient in the recipe for student success in physics.

The students who participated in the conceptual discussions reduced their level of misconceptions by 9-percentage points when compared to those who did not participate in the discussions. The students who participated in the conceptual discussions also showed a 7-percentage point increase in their average achievement when compared to the control group. The author cautions us, however, that though the results were statistically significant, the measured effect sizes were quite small. Eryilmaz, (2002) suggests this shows us just how resistant to change student misconceptions really are, and points us to

several other studies pointing to similar conclusions; Brown, (1989), Gunstone, (1987), Terry & Jones, (1986) and Maloney, (1984). He also references two additional studies, McConney, (1992) which used conceptual discussion to address student misconceptions in biology, and Nussbaum & Novick (1982), which used this method to address student misconceptions about gas particles. The author indicates that each of these studies came to similar conclusions as the current study (Eryilmaz, 2002). He does address the limitations in the data, but also explains a rigorous statistical attempt to address these limitations. This researcher, like several others previously mentioned, believes that more research needs to be done in the area of increasing student achievement in physics.

What follows next, is a list of criteria for determining whether or not a teacher or program is attempting to create conceptual change. As you read through the criteria, you will once again be reminded of Piaget's processes of assimilation, disequilibrium, accommodation, and organization.

Criteria for Addressing the Change Principle

1. Teacher begins lesson by questioning the students to find out what they know (or think they know) about the material to be covered.
2. Teacher begins with things the students tell him/her that are correct to serve as an anchor point as they start the lesson.
3. Teacher clearly establishes the context in which the material will be presented.
(See the context criteria presented earlier in this chapter).

4. Teacher uses analogies to bridge unfamiliar material with familiar material (comparing energy levels of an electron to the layers of an onion, for example).
5. Teacher sets up a situation in which the student experiences disequilibrium (they observe something that does not match their prediction, also called cognitive conflict).
6. Teacher “restricts the frame” for the students (helps them determine which information is relevant, and which information can be ignored; or sets up an experiment or demonstration that simplifies a difficult concept to clarify the relationship in question for the student).
7. Teacher uses multiple representations in the presentation of the material such as spoken words, written words, equations, graphs, tables, diagrams, or other representations.
8. If the teacher uses more than one representation, they take the time to explain how to translate the information from one form to the next.
9. The teacher repeats the exposure to the material being taught... but with each repetition, they add more “real life elements.”
10. The teacher has the student demonstrate their understanding of the concept being taught using spoken words, written words, equations, graphs, tables, diagrams, or other representations.

Examples of Successful Programs Implementing the Change Principle

The Modeling program begins each topic with a discussion about the description of the experiment to be carried out. The teacher serves as a moderator, non-judgmentally recording all suggestions and probing for clarification when necessary. This initial brainstorming activity engages the students in the thought process, and gets them thinking about elements within the system that are important, and those which are not. By soliciting input from the students about what can and cannot be measured in an experimental setting, the instructor can uncover misconceptions and synthetic models before the actual data taking occurs. Knowing this information initially gives the instructor insight on how to guide the students into setting up an experiment a particular way (for example, to create cognitive conflict, to serve as a bridge, or to restrict the frame).

The students then collect and analyze the data. During this stage, they are socially interacting with the instructor, and with each other. As they do this, they have time to test their ideas, to reflect on their own thought processes, and modify their existing mental model to the extent necessary to reach a more accurate understanding of the actual process or phenomenon.

The students then must present their model to the rest of the class in a variety of contexts. They must be able to translate between graphs, formulas, diagrams, and written words. Each translation from one form of communication to another serves as a point of reinforcement for the student as they accommodate their new model. Each new topic is explored in a similar fashion, so students get repeated exposure to the methodology of

model formation. As this happens, they rely less on the teacher, and more on their internalization of the process. All of these activities taken together have been shown to produce significant and lasting conceptual change in the studies we have previously examined.

Physics by Inquiry requires at the start of each new topic or subtopic that the students make detailed predictions about what will happen when an experiment is carried out. The instructor asks the students about their predictions to find out what they are thinking, and they are required to put their predictions in writing as well. The experiment is then carried out and once again, situations involving cognitive conflict, bridging, and frame restriction are all present, depending on the initial state of the learner. The point is that the initial predictions set the stage for what type of situation is to follow for the student.

Physics by Inquiry is purposefully set up to bring common misconceptions to the forefront. Students must reconcile their incorrect mental models with a more accurate understanding in their own words before they continue through the curriculum. As the context becomes more involved, carefully targeted questions are asked which cause the student to frequently reference earlier lessons in order to build a proof of their emerging mental model. Everything builds incrementally, following the belief that learning is a growth and not a transfer of knowledge. Previously mentioned studies have indicated quantifiable student gains in achievement using this method, and these studies also indicate that the change is long lasting; four years in one study (Francis et al, 1998).

The Physics Suite embodies a myriad of activities specifically targeted at assessing prior knowledge, creating cognitive conflict, building bridges, setting anchors as starting points, and honing the skills of reflection and self analysis. As described in the constructivism and context sections of this paper, the text, lab activities, and accessory materials used in The Physics Suite were born out of years of research in physics education and cognitive science (Redish, 2002). Therefore, utilizing research driven methods to create conceptual change is interspersed throughout both the text, and the lab-based portions of the curriculum.

All of the programs described above set up a state of disequilibrium for the students to come face to face with their misconceptions, show evidence of setting the context before introducing the new material, initially “restricting the frame” when a new topic is introduced, then gradually building in more real-life elements as the students become more comfortable with the material. These programs also show evidence of treating the learning environment as a social setting.

The programs also have a variety of ways to check for student understanding. Every program involves the students in expressing their ideas in writing, for example, making predictions, answering essay or short answer questions, or writing lab reports. They also utilize the spoken word. For example, in the Modeling program, students are required to conduct an experiment, gather data, make observations, and create a whiteboard explaining the entire process, including the results orally. Having seen this happen both as an observer and as a student myself, I can say with certainty that it is much more difficult than it may at first appear. Being able to put a scientific observation

and/or a mathematical relationship into words is not an easy task for many students. It takes practice, and each time the student goes through the process, they become more comfortable translating between numbers, graphs, equations, sentences, and discussions. The process forces the student to confront the situation in multiple contexts thereby increasing the likelihood of attaining a deeper understanding and a fundamental conceptual change if needed.

Every program also utilized equations, graphs, tables, and diagrams as well in an attempt to facilitate conceptual change. It should be noted, however that the Maryland program was the only one that stressed not only the importance of using multiple representations to present a new concept, but also taking the time to ensure that your students are able to understand how to *translate* from one representation to the next (being able to describe the shape of a position time graph in terms of a student walking across the room, for example). The Modeling program does involve the students making translations, as does Physics by Inquiry, but Maryland spoke to the importance of teaching representation translation specifically.

It stands to reason that the use of multiple representations and multiple contexts to explore a concept would reach a wider range of students. In the fourth of Redish's five principles, we discuss the implications of the fact that each student is an individual, and has his or her own style of learning.

4.The Individuality Principle

Definition

Each student has a unique approach to learning.

Elaboration

Because we are all individuals with our own unique makeup and our own unique set of experiences, Redish tells us not to look for a “one size fits all” approach to teaching that will work with all students under all circumstances. Instead, he proposes using a variety of approaches in a variety of contexts to stand the best chance of reaching the largest number of students.

He also warns us against using the teaching strategies we most favored when we were physics students. He reminds us that not all of our students are going to be as enthusiastic and passionate about the subject matter as we were. Because of this, the instructional methods that worked well for us, may not work well for the majority of our students. There are many different ways to measure intelligence, and as such, we as physics educators should attempt to tap into as many of them as possible. It is our responsibility to utilize as many vehicles of delivery as possible to address the individual learning approaches of our students.

Connections to the Learning Literature

Much of the work concerning the different ways in which people learn was pioneered by Howard Gardner in 1983. He believed that basing a person’s intelligence solely on the results of an I.Q. test was too limiting. Instead, he proposed that

intelligence could be broken into eight distinct categories. The categories, taken from Armstrong (1994), are as follows:

Linguistic: the intelligence of words.

Logical-mathematical: the intelligence of numbers and reasoning.

Spatial: the intelligence of pictures and images.

Musical: the intelligence of tone, rhythm, and timbre.

Body-Kinesthetic: the intelligence of the whole body and the hands.

Interpersonal: the intelligence of social interactions.

Intrapersonal: the intelligence of self-knowledge.

And Gardner added two additional intelligences in the mid 1990's:

Naturalistic: the intelligence of nurturing and relating to one's natural surroundings.

Existential: the intelligence of the spiritual realm, that which exists beyond sensory data.

(Gardner, 2003)

Rationale for Addressing Student Individuality

Armstrong (1994) commented that despite our best efforts, much of the praise and recognition in our schools has been aimed at people who possess the linguistic and logical-mathematical forms of intelligence. We hold in high regard the articulate or logical people of our culture. However, Gardner says that we should also place equal attention on individuals who show gifts in the other intelligences: the artists, architects, musicians, naturalists, designers, dancers, therapists, entrepreneurs, and others who

enrich the world in which we live. The education community needs to broaden its description of what constitutes intelligence.

Seider (2009), a former middle school English teacher and now Harvard professor, talks about his journey as a public school teacher on the road to discovering the benefits of using the multiple intelligences model in his classroom to reach more of his students. He recalls observing a group of his struggling students in a different environment; the football field. He noticed the ability these kids were able to demonstrate as they memorized and executed intricate football plays. It was at that moment that he made the realization “Hey, these kids are really smart!” And from that moment on, he began to tune into the various ways students can demonstrate intelligence.

From a cultural standpoint, Lee (1997) provides an interesting argument in her commentary on what actually constitutes the nature of science, and how our narrow definition may be shutting people of other cultural backgrounds out of the scientific process. Her ideas will be expanded on in a later section devoted specifically to addressing the needs of diverse learners.

Huitt (2003) and Driscoll (2005), explain that students stand a much better chance of converting incoming information into permanent long-term memory if they find the information interesting. Since all students are different, using as many different delivery methods as possible or practical will no doubt reach more individual students, and possibly allow those students a more rapid access to higher levels of thinking.

Crawford (2000) believes that using methods in science classes that allow the students to use more of their senses to absorb the new information, can lead to a deeper

level of understanding. This allows them more opportunity to create their own mental framework of the concept being studied, because there are a greater variety of methods available to process the incoming information.

Beerer & Bozdin (2004) remind us that each student has their own cultural lens through which they view the world. Because of this, it is important for the teacher to present the material in a variety of contexts in the hopes of finding one that will work for every student. This takes us back to trying to represent as many different types of intelligence as possible as we design and implement our curriculum.

Finally, Redish (2002) also states that one method will not work for every student. He told us in the discussion of the Change principle that using multiple representations to present information increases the chance for a successful transmission of information from teacher to student. He warns us however that switching from one type of representation to another (from a graph to an equation for example) may be a problem for our students. Multiple representations are a powerful mechanism for transmitting information, but they are useless if the student gets lost in the translation.

Evidence for Gains in Student Achievement when the Curriculum Addresses Multiple Intelligences

Studies that link student achievement to addressing multiple intelligences in the classroom are scarce. The overall impression in the literature is that teachers instinctively recognize the importance of addressing multiple intelligences when they work with students, but quantifiable evidence of actual gains in achievement are noticeably absent. Not one study was found relating multiple intelligences to physics education specifically.

However, there was a teacher action research study conducted to determine the impact of implementing the theory of multiple intelligences (MI) in the curriculum for both foreign language and English as a Second Language (ESL) students. The study consisted of 23 foreign language and ESL teachers and 650 students from eight states and three countries, and it was designed to apply MI theory to foreign and ESL language learners in grades K-12 (Hall-Haley, 2004).

The study began with each student taking an MI survey to determine the characteristics of their intelligence profile. The survey was adapted from Armstrong's book *Seven Kinds of Smart* (1994). The teachers then used the results of these surveys in their instructional planning.

The researcher was interested in examining the effects of the MI interventions developed by the teachers as a result of the information contained on the initial student surveys. Qualitative data included teachers' electronic communications with the researcher, weekly activity logs with detailed notes, lesson plans, project descriptions, student exit slips (three or four short answer questions answered by students at the end of randomly selected classes to determine their reactions to MI instructional strategies and assessment), and participants' comments at the end of the study (Hall-Haley, 2004). Student performance and achievement were determined quantitatively by data that consisted of student grades before and after the MI study, as recorded by participating teachers.

Students in the experimental group received instruction that incorporated the MI theory. The author describes the lessons as "more learner centered, and containing a

wide variety of instructional strategies, including demonstrations, modeling, feedback response, learning centers, discussion, students' responses to learning experiences, total physical response (TPR), hands-on experiences, and cooperative learning" (Hall-Haley, 2004, p.168).

Students in the control group were taught in a teacher-centered approach. The teacher closely followed the textbook, and relied exclusively on rote drill and memorization. There were no cooperative learning groups, no interactive activities, and nothing hands-on. The text and occasional overheads were the only visuals used.

The effects of MI intervention were documented qualitatively through observations, exit slips, survey checklists and student reactions. The author tells us that subsequent analysis of this data suggested that;

How one is taught, what strategies are used, and in what manner information is presented can and do affect student learning. Learner-centered instruction from the perspective of multiple intelligences further demonstrated students' strengths and weaknesses can be affected by a teacher's pedagogical style (Hall-Haley, 2004, p.171).

The author states that most students in both the experimental and control groups demonstrated growth in oral and written proficiency at the end of the marking period, however results showed that students in experimental groups receiving MI-based instruction outperformed those in the control groups. She also tells us:

Additionally, the exit slips demonstrated a high degree of satisfaction and positive attitude toward foreign/second language study. Students in the experimental classes were more enthusiastic about learning and behavior problems were minimized. [The] teachers felt that their classroom management skills were enhanced. (p.171)

She comments further on this affective outcome. She believes that:

Most students expressed positive feelings about teachers using a variety of instructional strategies as well as assessment practices that addressed the multiple intelligences. Teachers attributed this positive reaction to the greater degree of flexibility, variety, and choice that MI strategies allowed students in their classrooms. (p.171)

In her conclusion, she does concede that student grades may not be the best predictor of achievement, because the grading scales were not uniform across the study, nor were the assessment tools used to generate those grades. She also notes that the MI interventions were not consistent across each teacher, that is, they were individualized and therefore varied.

Though this study was certainly not perfect, it did provide a glimpse into what most every teacher already intuitively knows: If you teach to the strengths of your students, you will see larger gains in achievement. More research is certainly needed in this area.

This brief literature connection is certainly not exhaustive, but it does provide evidence that educators and education researchers alike are supporting the idea that students are not identical blank slates. They come to us with different strengths and weaknesses, different levels of expertise in our subject area, and they have all had different experiences prior to our meeting them. Because of this, it only makes sense that good teaching would take these fundamental differences into account. What follows is a list of criteria to determine whether a teacher or a program is taking the Individuality principle into account. You will notice that once again, several of the aspects of individuality principle overlap with some of the other principles (such as the Context principle and the Change principle).

Criteria for Demonstrating Awareness of the Individuality Principle

Criteria for demonstrating the Individuality Principle:

1. This teacher believes that no one learning style is superior to all others, and no one style works best with all students
2. This teacher utilizes a variety of *contexts* to present material (see context criteria).
3. This teacher utilizes a variety of *analogies* to present material (see change criteria)
4. This teacher utilizes *multiple representations* to present material (see change criteria).

5. This teacher demonstrates teaching to the following intelligence types:

Linguistic: the intelligence of words.

Logical-mathematical: the intelligence of numbers and reasoning.

Spatial: the intelligence of pictures and images.

Musical: the intelligence of tone, rhythm, and timbre.

Bodily-Kinesthetic: the intelligence of the whole body and the hands.

Interpersonal: the intelligence of social interactions.

Intrapersonal: the intelligence of self-knowledge.

Naturalist (environmental) intelligence.

6. When checking for understanding, this teacher evaluates each type of intelligence mentioned in #5.

7. This teacher modifies his or her lessons specifically to accommodate students of cultures other than the dominant culture.
8. This teacher modifies his or her lessons specifically to accommodate students with special needs.

An Example of Using Multiple Intelligences in a High School Physics Classroom

The following examples come from Dr. Peggy Bertrand, an Advanced Placement Physics teacher at Oak Ridge High School in Oak Ridge Tennessee. Bertrand (n.d.) reports that in her experience, teachers who use MI theory in their classrooms often report greater success with and intellectual engagement with those students who are not necessarily verbal-linguistic or logico-mathematical learners.

Bertrand uses graphical representations and diagrams to highlight spatial intelligence. She believes that physics is the most spatial of the basic sciences. She has the students move around the room to demonstrate concepts such as velocity, and acceleration. This blends spatial intelligence with body-kinesthetic intelligence. When the topic of net force comes up in physics, problems involving elevators inevitably arise. She actually plays elevator music in the classroom and has the students act out with their bodies how they would feel when the elevator starts moving (the students bend their knees), then moves at a constant velocity (they stand normally), then slows down (they rise on their tiptoes) etc... she says that abstract concepts such as force and acceleration make sense to kinesthetic learners when they are addressed in terms of how they make one's body feel.

In her unit on sound, Bertrand has the students attempt to play the C-major chord with tubes of plastic and graduated cylinders. The class relies on the musically intelligent students to tell them when the proper blend of frequencies has been attained. She also uses the theme music from the game show Jeopardy to train her Advanced Placement students to gage how much time they spend on a particular question (the song is 30 seconds long). She tells them they need to answer each question in about a minute if they hope to answer every question in the time allotted. The Theme song helps them keep in mind how long a minute is (if they hear it twice).

Like so many others have stated in this paper, Bertrand uses cooperative learning activities and laboratory activities to promote social learning and interpersonal intelligence. Also in line with what we have learned so far, she gives the students time to reflect on their thoughts and construct their ideas in a journal, thereby building intrapersonal intelligence. She believes this aids them in addressing and eliminating stubborn misconceptions they may have about a particular topic area. She does not address naturalistic intelligence, but I believe that something as simple as using a GPS receiver to teach students about vectors in an outdoor setting could spark an interest in students with an affinity toward nature. She presents some very interesting approaches to teaching physics that suggest that it can be taught using Multiple Intelligences as the framework for development.

Examples of Programs Embracing the Individuality Principle

In terms of Gardener's multiple intelligences, used here as one indicator that a program attends to student individuality, the Modeling, Physics by Inquiry and Physics Suite programs all address linguistic, logical-mathematical, spatial (in terms of constructing and interpreting graphs, diagrams, and pictures), body-kinesthetic (in the context of manipulating laboratory equipment), interpersonal, and intrapersonal (in the context of self reflection and meta-cognition) intelligences, though not musical and naturalist intelligence types. Not one program mentioned either of these intelligences in their literature.

These programs also assess every intelligence type except musical and naturalistic, although each places different weights on the importance of each intelligence type. For example, the Modeling program involves students in constructing a graph and translating that graph into a mathematical relationship, which then gets translated into a sentence. They do this with *every* new concept. Physics by Inquiry involves students in graphing data at times, and then translating those results into succinct statements to explain that data, although they do not use this method for *every* new concept. The Physics Suite has materials that would allow the teacher to assess nearly every intelligence listed, but the choice is left up to the instructor.

None of these programs specifically stated that they modified their course structure or lesson plans to accommodate students of different cultures. However, the evidence suggests that the majority of them use a constructivist, student centered, active learning environment where cooperation and collaboration are the favored method of

instruction, and where the student, not the teacher, is responsible for constructing their own knowledge structure. According to Haury (1993), the research also seems to indicate that that courses taught in this manner may be especially valuable for many different struggling and underrepresented populations (he refers to this manner of teaching as “inquiry-oriented teaching”). He goes on to mention that in one study, language-minority students were found to acquire scientific ways of thinking, talking, and writing through inquiry-oriented teaching (Rosebery et al., 1990). Inquiry-oriented science teaching was shown to promote development of classification skills and oral communication skills among bilingual third graders (Rodriguez & Bethel, 1983). Active explorations in science have been advocated for teaching deaf students (Chira, 1990). Finally, experiential instructional approaches using ordinary life experiences are considered to be more compatible with Native American viewpoints than are text-based approaches (Taylor, 1988).

This research seems to suggest that when students are allowed to construct their own knowledge in an active and social environment using hands on, real life, relevant materials, there is a benefit for underrepresented students. The social aspect of the learning environment will be discussed next. The fifth and final of Redish's principles is the Social Learning Principle.

5.The Social Learning Principle

Definition

Effective learning occurs most often through direct social interactions.

Elaboration

Redish believes, as did Lev Vygotsky, that higher order thinking develops through a series of social interactions. By being part of a group and being able to ask questions and share ideas, students can more effectively pass through ever-higher stages of development. When a student “sort of knows how to do something” but is not quite able to complete the task alone, Vygotsky referred to this as being in the Zone of Proximal Development. He believed that the culture in which the student was immersed, and the nature of the social interactions that the student has with others around her can cause the time required to pass through the Zone of Proximal Development to vary. This implies that, as educators, we have the ability to alter the time required for a student to learn a new skill.

Connections to the Literature

The cornerstone of this view of human development is that higher order functions develop as a result of social interaction. This perspective draws heavily on the work of Lev Vygotsky. He firmly believed that one could not study the development of a student by simply looking at the individual. In Vygotsky’s model, development occurs as social relations are converted into mental functions. He focused on the interaction between the

individual and the context in which the individual exists, and believed this interaction could give answers to the nature of development (Driscoll, 2005).

Vygotsky believed that any higher mental function had to pass from being external to internal. Internalization can be understood as learning the ropes, or figuring out how to do something. For example the ability to color a picture or dance are skills possessed by “experts” in the society, and initially beyond what a child is able to do. The child gradually acquires these skills as a result of being immersed within her culture. Eventually, the child internalizes the skills to a level where she can truly make them her own, and at this stage, she is not simply copying the societal experts she learned from, but rather, she is becoming an expert herself (Driscoll, 2005). The student works with someone who is farther along in their skill development, and that person assists the student through a process called scaffolding, in which the master guides the student through the process, and gradually does less and less of the process, allowing the student to do more and more (a process called fading).

In order for these children to become experts, Vygotsky believed that they had to pass through something called the Zone of Proximal Development (ZPD). This zone is that grey area where the student has not yet mastered the skill, but is in the process of doing so. When a student is in the ZPD, they have not yet become comfortable with the new skill, but are laying the groundwork so that eventually, they will be able to complete the skill without the assistance of others. According to Vygotsky, the lower limit of the ZPD is fixed by the actual level of development that a child demonstrates, but the upper level can be moved by various types of instruction and stimulation (Driscoll, 2005). In

other words, the societal interactions experienced by the student can lead to delays or accelerations in their development as they pass through the ZPD. This certainly has strong implications for education.

Abell & Lederman (2007) state that in a constructivist learning environment, “Meanings are socially constructed [and] understanding is enriched by engagement of ideas in concert with other people” (p.809). Chickering & Gamson (1987) state the importance of open two-way communication between instructor and student, as well as among students in their seven principles for good practice in undergraduate education. In a study to capture and model the process of conceptual change, Vosniadou (1994), states that encouraging children to provide verbal explanations of what they are observing, to share these explanations with other children, to defend against criticism, and to compare their explanations to those of the experts, are all possible vehicles to promote deep and lasting conceptual change in their mental models of physical science. In a related article, Vosniadou et. al. (2001) remind us that

Learning is not an activity that occurs only in the head, but it is also an activity that happens in a social and cultural context... [and] since learning is not an individual but a social affair, schools should encourage children work with other children and learn from them in ways that take into consideration their individual differences. (p.382)

Heller, Heller, & Hsu, designers of the Minnesota Model of physics instruction, note that cooperative group problem solving, which involves students working in carefully designed groups with specific roles assigned to them by the instructor or supervisor, provides the students with a scaffold, in which both conceptual and procedural knowledge is distributed throughout the group. By sharing the workload and modeling

the problem solving strategies in a group format, they have found that their students are able to apply problem-solving strategies faster than they were able to when they worked alone. In a related article, Heller, Keith, & Anderson (1992) attempted to find out which components of problem solving are performed better in groups. They found that in groups, students collectively generated more useful physics descriptions with fewer conceptual difficulties than the best problem solvers from each group could generate alone. They also found that students taught using cooperative group problem solving strategies were able to score significantly higher on context rich problems than students taught in a traditional setting, even when the cooperative group students were solving these problems alone. In other words, the cooperative group training helped these students to later become better problem solvers than the students who were taught by the traditional lecture method. In the list of criteria that follows, attention is paid to the atmosphere of the classroom. The criteria were adapted from Chickering & Gamson's *Seven Principles for Good Practice in Undergraduate Education*, which was obtained from the American Association of Higher Education.

Criteria for Observing Adherence to the Social Learning Principle

1. The teacher creates an atmosphere where teacher-student interactions are encouraged and the conversation flows both ways. The teacher communicates often with the students, and the students feel comfortable communicating often with teacher as well.

2. The teacher encourages the team approach to learning, that is, working in groups to solve problems, discuss questions, work on projects or defend and/or justify ideas.
3. The teacher encourages discussion of the material among the students. The classroom is not silent as the students are free to discuss ideas.
4. This teacher keeps the students on task. The teacher is always around to guide a wandering conversation back to the topic of the lesson.
5. Shared responsibility. The teacher ensures that all members of the group participate. The teacher may assign specific roles for each student, or make sure that each student is asked particular question during an assessment. Basically, the teacher makes it clear to the group that each member will be responsible for learning the material, and that nobody will be permitted to passively watch their group members without taking ownership.

Examples of Programs Using the Social Learning Principle

Each of the programs studied mentioned the importance of social interactions in their classrooms. The Modeling program involves starting investigations with a large group discussion of the possible variables to be tested. The students then break into small group discussions as the experiments take place. The cycle concludes with the small group then explaining their procedure and findings to the large group and opening the floor for questions.

Physics by Inquiry relies heavily on small groups interactions, with the teacher roaming from group to group, assessing progress and checking for understanding. A

great deal of time in this program spent by the students is in the form of one-on-one discussions with one another about predictions and observations related to the concept being studied.

The Physics Suite has many different aspects to choose from, but as we have seen in our earlier discussions, strong teacher-student communication is stressed. Like the other programs, Physics Suite recognizes the value of collaborative learning, and encourages students to discuss and defend their reasoning throughout the learning process.

Each of the three programs also has a mechanism for ensuring that all students within a small group take ownership in both the process and the final product. In Physics by Inquiry, if the teacher senses that one student is dominating the situation, the teacher will begin to question the other student exclusively to ensure that they too understand what is going on in the lesson. In Modeling, the students must present their findings as a group, and each member of the group has to participate in the presentation. Also, each member of the group has to be able to field questions both from the teacher as well as from their classmates. The Physics Suite utilized classroom discussions and both small and large group formats in various aspects of its curriculum as well.

Learning does not occur in a vacuum. Learning depends heavily upon social interactions between learner and teacher, and among fellow learners as well. It is these social interactions that guide a learner through the zone of proximal development to deeper levels of understanding. Because learning relies on social interactions, attention

should be paid to the social learning principle when designing and implementing physics curricula.

In Chapter 3, we will examine one of the physics teacher training programs mentioned earlier, the University of Wisconsin—River Falls summer certification program for teachers. It has demonstrated that it embodies aspects of the five principles that are important for teaching physics with the goal of changing established mental models and being sensitive to the needs of individual students. Data was gathered in the form of a survey, and from that survey, specific participants were chosen as case studies. These individuals were interviewed, and samples of work from their students as well as lesson plans were gathered to search for evidence of Redish's Five Principles.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

In this chapter, the research procedures used in this study are described. A history and overview of the Summer Physics Certification at the University of Wisconsin—River Falls is provided in order to give the context in which this study is situated. Subsequently, the rationale for conducting a mixed-methods study including surveys and case studies is explained. The instrument development, sampling, data collection and analysis methods are reviewed as well as the participant selection process, and data collection and analysis for the case studies. Also included in this chapter is a discussion of the study quality, as well as the potential limitations of the study. Finally, my research perspective is presented in order to give the reader a sense of the personal “lens” that I brought to the research.

Context of the Study

Within the state of Wisconsin, the University of Wisconsin – River Falls is attempting to address the growing shortage of certified high school physics teachers. We will take a closer look at the program at UW-RF and the methods they are using to prepare physics teachers, and see how closely the program aligns with Redish’s five research based principles for creating a deeper understanding of physics. The information to follow comes directly from Dr. Eileen Korenic, the current Program

Director. In chapter 4, we will hear from program participants by examining survey and interview responses, as well as portfolio artifacts. Since 1986, the UW-River Falls physics department has provided a series of summer courses for secondary science teachers to allow them to gain initial physics licensure or renew their existing physics license. According to Korenic (2006), records indicate that more than half of the physics teachers in the state of Wisconsin have taken at least one summer course at UW-River Falls. From its inception in 1986 up until February 2010, the program has worked with over 200 students, and its scope has also broadened (Korenic, 2010). It started out as a program designed to address physics certification needs only, but has evolved into a program wherein some students are seeking initial licensure, some are seeking license renewal, and some are working toward a Master's degree specializing in physics education. Through exit surveys, many of the participants have indicated that the coursework provided by UW-River Falls has enhanced their own understanding of physics, and has also assisted them in being able to teach the subject to their students more effectively

Korenic (2006) noted that in yearly needs assessments with summer teacher participants, UW-River Falls has been seeing a dramatically increased need for the teachers to be able to bring their new-learned skills and familiarity with new technology to their students. Teachers have recently identified that their greatest need is to have the equipment in their own classrooms that they learned to use in their summer coursework. Most of the teachers served by this program report having very limited budgets, which makes it difficult for them to develop hands-on experiences for their students and forces

them into a demonstration-only mode of teaching, a mode that current research is showing may not be as effective at promoting deeper student understanding in physics. She mentioned that some of the teachers believe so strongly in the value of hands-on, inquiry or discovery learning, that they spend hundreds of dollars of their own money to make sure their students have what they need if the district is not able to provide it. It has been the case throughout the operation of this program that a significant number of the teachers are from rural, financially strapped districts. According to Korenic (2006), the UWRF summer program believes that teachers need not only access to the new technology, but also training and staff development on how to use that technology.

She goes on to say that UW-River Falls is the only northern Wisconsin, rural access Institution of Higher Education to offer a comprehensive summer-only program committed to sustaining professional development for physics teachers. In fact, physics programs designed specifically for educators are currently somewhat of a rarity as was seen in Chapter 2, although the physics education research community is working to change that. The River Falls program aims to allow science teachers to obtain licensure, content competency, and training in best practices use of physics content-related educational technology. This 25 year-old program has consistently enrolled higher percentages of women than are represented in the current secondary physics teacher population, and Korenic reports that the program continues to look for new ways to reach out to women and other under-represented groups in the population (2006). A breakdown of the official program goals, changes in teacher participants, and projected

changes in students is provided in the following table based on information furnished by the program.

Table 1. Official program goals, teacher participant changes, and projected student changes as a result of participation in the River Falls Summer Physics Program.

-
- I. Official program goals:
 - 1. To provide opportunities that prepare teachers to demonstrate the competencies that will be end-tested for licensure.
 - 2. To provide professional development coursework that trains teachers in recent physics developments and physics content-related educational technology including theoretical, experimental, and industrial progress.
 - 3. To provide training and assistance in the choice and use physics laboratory equipment (Vernier, PASCO etc...).
 - II. The changes that UWRF expects to see in their teacher-students are as follows:
 - 1. They will increase their knowledge of physics.
 - 2. They will develop better instructional strategies in the field of physics.
 - 3. They will be able to make more informed choices of physics content to provide to their students.
 - 4. They will become more confident in their teaching of physics.
 - 5. They will become better able to select and properly use physics laboratory equipment.
 - III. The expected changes in the students of these high school teachers are as follows:
 - 1. There will be an increase in enrollment because of a better learning environment.
 - 2. Since the teachers will have both a broader and deeper understanding of current physics research and pedagogy, the students taking their classes will exit with a deeper understanding of physics and physics concepts.
 - 3. The students will be better prepared to meet state standards related to physics because their teachers will have learned new strategies.

Table 1 Continued

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4. Students will develop more sophisticated and more accurate mental models relating to physics because the teachers will be trained in methods of assimilating new physics knowledge into existing physics knowledge. The teachers will use a variety of approaches including laboratory exercises, problem solving, lecture/discussion, sharing, modeling, and inquiry based methods as vehicles for content delivery.
-

The program consists of three 3-week summer workshops—Mechanics, Electricity & Magnetism, and Modern Physics. These courses are offered on a three-year rotation, one each summer, and they are the core courses needed to obtain licensure in Wisconsin with competency in general physics content. These courses have been created to address specifically the primary standard defined by the Wisconsin Department of Public Instruction which states that teachers must know the subject they are teaching; including central concepts, tools of inquiry, and structures of the disciplines. Four semester hours of graduate credit are granted for each of these courses.

Korenic (2006) uses the word “constructivist” to describe the instructional approach of the program. Components present within each course include direct instruction, discussion sessions, laboratory experience, training in curriculum design, and the use of teaching resources intended to support teaching and learning standards. Throughout each course, faculty attempt to provide students with the opportunity to create their own conceptual framework for what it is they are observing. Instruction occurs in a small group setting of 24 or less and students share ideas with each other throughout the entire process. At the conclusion of every course, the students prepare a teaching activity utilizing the content from the course and the Wisconsin State Standards

for Science that they present to the group in a sharing session. It is during these sharing sessions that participants have the chance to observe standards based lessons, laboratory experiments, student projects, and other classroom activities presented by their classmates. It is also during these sessions that questions can be addressed, and the participants can determine how or if the particular lesson being taught could be applied to their personal situation. These components were also present in Redish's framework for a constructivist instructional setting described in Chapter 2. Though the River Falls program does not follow the Physics by Inquiry or Modeling curriculum exclusively, it draws upon aspects of both programs.

There are several two-credit courses offered each summer, which provide an additional tier of physics understanding. These courses include, but are not limited to the following: Acoustics, Optics, Astronomy, Thermodynamics, and Laser physics. This list is continually evolving as the program attempts to reflect advances and changes in emphasis within the field of physics. These courses are typically one or two weeks in length.

Every course includes at least one session for participant-presented activities, laboratories, demonstrations, and curriculum design. The participants are required to show the link between the activities they present and the State of Wisconsin Model Academic Standards for Science (Korenic, 2006). Each participant shares the directions for their activity and how it specifically addresses a learner's needs in the form of a written document. The sharing session results in the generation of a set of activities available to all teacher participants and their districts. The advantage to this activity is

that the participants not only create their own classroom activities, they will be able to see first-hand how each of their colleagues' activities work through direct observation (Korenic, 2006). During this session, the participants can ask questions to ensure they will be successful if they later decide to replicate the activity with their own students.

Due to previously supported Eisenhower programs at UWRF, nearly 160 teachers have been certified to teach secondary school physics since 1986. According to Korenic (2006), analysis of needs assessment surveys administered to program participants has identified a need for coursework, activities, and training in current developments in the field of physics and in integration of technology in physics instruction. Over the past several summers, three such courses have been tested as special "Topics in Physics" courses. They include Technology for Physics in the Secondary Classroom, Modeling Physics in the Secondary Classroom, and Electronic Circuits. These were conducted as one-week two-credit courses. According to Korenic, exit survey responses showed the students responded positively to these new courses. For example, regarding the 2007 Digital Electronics topic course, one participant said "[I liked] the different ways of learning the material; lecture, pen and paper, P-SPICE, building circuits... all very needed in the learning process." And another participant stated they were impressed with "Just how far I realized I had come in understanding the course material. I was very nervous about it on Tuesday, but by Friday, I was already thinking of ways to apply the concepts in [my] school." There are other courses currently being considered such as Fusion, Survival in Space, Holography, and Optical Communication. All of these and other topics have been identified in informal brainstorming sessions among faculty and

participating students as being extremely important in two main needs areas for the secondary level teachers: (1) generating activities for use with K-12 students, and (2) enhancing participant understanding of current physics research and industrial applications.

All of the existing and proposed workshops, coursework, and professional development activities are offered for graduate credit. An important point is that these courses are not regular university offerings, but instead are courses specifically tailored to meet the needs of the teacher participants. As mentioned previously in this paper, research strongly suggests that physics programs designed specifically for educators should look different than physics programs designed for engineers and people going into other fields of study. UWRF has been using the results of this research to create an educator-specific physics teacher certification program.

Exit survey data has shown that in informal group discussions with the teacher participants as well as in the needs assessment conducted each year, teachers have responded positively and enthusiastically to the coursework, the increase in confidence they experience as they increase and update their content and pedagogical knowledge, and the lab and demonstration sharing sessions.

Korenic (2006) states that the UWRF program conducts an ongoing evaluation, using a variety of data sources in the process including:

- A participant questionnaire to provide feedback to directors and instructors for all courses and workshops.

- Tests, problem sets, laboratory notebooks, and classroom participation to provide more immediate measures of gains in content knowledge.
- Demonstrations, laboratory activities, or other teaching techniques that may later be used by participants are presented in a large group format at the conclusion of each course.

The program has been funded by multiple sources, including Eisenhower, the Elementary and Secondary Education Act, the National Science Foundation, the corporate sector, participating school districts, and the UW-system. The program has assisted nearly 160 teachers in achieving physics licensure, and estimates approximately 100 additional teachers seeking training as of summer, 2006. The enrollment for the summer of 2009 core course was 24 students, of which two were seeking physics licenses (Korenic, 2010). Korenic reported that the trend among most participants now seems to be using the program as a vehicle for the salary increase that comes with earning a Master's Degree in most districts, rather than primarily using the program to add physics as an additional certification. The exit survey data provided by Korenic seems to indicate that "personal understanding and interest" is the most common reason why the participants take the courses, with "maintaining licensure" the second choice.

The UWRF program notes that it has attracted and supported an increasing number of female physics teachers. As of 2009, thirty-five of the one hundred-nine current participants are women (Korenic, 2010). The UWRF program philosophy is to discourage the use of crossover teachers (teachers certified in science fields other than physics) or the teaching of physics by teachers with no science background at all, because

the research suggests this may not be as effective as having a confident, competent, and well-trained physics teacher holding that position.

Research Procedures

The purpose of this study was twofold. The first purpose was to explore methods of teaching physics within the context of a mature, apparently successful and well-designed baccalaureate or graduate program, in this instance the UWRF program, that allows science teachers to increase their knowledge of physics. The second purpose was to gather data from secondary level physics teachers who had participated in the program in an attempt to see how much carry-over existed between how these teachers were taught, and how they utilized what they had learned with their own students. Five principles to establish lasting conceptual change and deeper processing of physics topics developed by physicist and long-time physics education researcher E. F. “Joe” Redish were used as a framework upon which research based criteria were established, and it was against these criteria that the university programs were compared. These same criteria were used in the high school classrooms. The principles laid out by Redish are as follows; the Constructivism Principle, the Context Principle, the Change Principle, the Individuality Principle, and the Social Learning Principle. Each of these principles are defined and elaborated on throughout Chapter 2.

Overall Research Design

A sequential mixed-methods design was chosen for this study (Creswell, 2008). The study is sequential in that quantitative data was acquired first through the use of a survey, and from this quantitative data, case study participants were then selected to obtain a deeper level of understanding as to what exactly was occurring within the classrooms of these teachers. The case study data was of a qualitative nature. Because both qualitative and quantitative data were used, the study is considered to be a mixed-methods design. This method was selected to strengthen the validity of the results by triangulating data from multiple sources including a survey, case study interviews, and portfolio data (Greene, Caracelli, & Graham, 1989). Realizing that all methods of measurement have their biases and limitations, it was hoped that the survey would provide a picture of what the teachers believed were important aspects of physics teaching and what they believed they were doing in their classrooms, while the subsequent interview and portfolio data would provide more direct evidence of what was actually occurring within these classrooms. Acquiring multiple forms of data in this way served a complementary purpose in that both qualitative and quantitative methods were used to measure aspects of physics teaching that, when taken together, both enriched and elaborated on the understanding of the experiences of the participants in the River Falls program, the value they placed on various aspects of the program, and the degree to which the participants carried valued practices over into their own classrooms (Greene et. al, 1989).

Identifying a Framework for Effective Physics
Teaching to Guide Data Collection and Analysis

From 2007-2010, a review of the literature was conducted to research effective methods of creating lasting conceptual change in the minds of physics students at both the high school and introductory college level. A common theme emerged that suggested university programs designed to train students to become physics teachers should look different than physics programs for physicists and engineers. A long-time physicist and physics education expert, E. F. “Joe” Redish from the University of Maryland identified five overarching principles that researchers within the physics education community deemed important in any physics education program. Further support for these principles (The Constructivist Principle, the Context Principle, the Change Principle, the Individuality Principle, and the Social Learning Principle), was found in the physics education research literature.

In the summer of 2009, literature pertaining to physics programs for educators was then studied to determine whether programs widely considered exemplary were indeed aligned with the five aforementioned principles. It was decided that three such programs provided sufficient evidence of adherence to these principles. They were the Physics by Inquiry program from the University of Washington, Modeling from Arizona State University, and the Physics Suite from the University of Maryland. Literature concerning these programs, as well as additional literature on physics teacher training programs, was then studied to develop a picture of classroom practices which embrace

the five principles laid out by Redish, and that could be used as evidence of effective physics teaching during the different stages of data collection.

Methods of Data Collection and Analysis

The following table presents the overall plan and timeline for this study. The first column contains the research question being asked, the second column depicts the methods used to obtain the information, and the third column identifies who or where the information came from.

Table 2. Research design matrix

Research Questions	Data Collection and Analysis	Participants and Timeline
1. What are the components of a program specifically designed to train physics teachers?	Literature review Research on UW-RF Summer Physics Program	2007-2010 Dr. Eileen Korenic, 2009-2010
2. What aspects of a program specifically designed to train physics teachers are present in the UW-RF Summer Physics Program?	Online survey- Quantitative and qualitative analysis Case study follow up questions through audio-taped interviews- qualitative analysis Portfolios showing examples of utilization of physics teaching strategies explained in research question #1- Qualitative analysis	All teachers who have taken at least one course in the UW-RF Summer Physics Program. February-May 2010. Seven purposefully selected Summer Physics Program participants June - September 2010

Table 2 Continued

3. What aspects of a program specifically designed to train physics teachers are viewed as important and/or useful by the UW-RF Summer Physics participants?	Online survey- Quantitative and qualitative analysis Case study follow up questions through audio-taped interviews- qualitative analysis Portfolios showing examples of utilization of physics teaching strategies explained in research question #1- Qualitative analysis	Seven purposefully selected Summer Physics Program participants June - September 2010
4. What aspects of a program specifically designed to train physics teachers are carried over into the actual classroom practice of participants in the UW-RF Summer Physics Program?	Online survey- Quantitative and qualitative analysis Case study follow up questions through audio-taped interviews- qualitative analysis Portfolios showing examples of utilization of physics teaching strategies explained in research question #1- Qualitative analysis	Seven purposefully selected Summer Physics Program participants June - September 2010

What follows is a description of the physics teacher survey, the case study selection process, the design and implementation of the case study interview, and the construction of the case study portfolio.

The Physics Teacher Survey

In the fall of 2009, a survey was created based on Redish's five principles and examples of classroom practices aligned with the principles evident in the research surrounding the three exemplary physics teacher training programs mentioned earlier,

and selected other programs. The first section focused on demographic data regarding the teacher and his or her school. The next section included 27 questions that focused on teaching and learning practices associated with Redish's principles. The following table illustrates the alignment of the survey item to a particular Redish principle. Notice also that some items align with more than one principle. The criteria used to align the survey question with a particular Redish principle can be found in Chapter 2.

Table 3. Alignment of survey items with Redish principles.

Item #	<u>Question</u>	<u>Principle</u>	<u>Criteria #</u>
1	When a new topic is introduced, the teacher provides some form of engagement to arouse the curiosity of the student such as a demonstration, a thought provoking question, or a classroom discussion.	Constructivist	1
2	When a new topic is introduced, the teacher assesses students' prior knowledge to modify instruction.	Constructivist Change	1 1,2
3	Students explore concepts by gathering data and searching for patterns or relationships.	Constructivist	2,5
4	The students are encouraged to explain observations in their own words verbally, in writing or by other means.	Constructivist	6,8,10,12
5	The students are encouraged to justify or defend their points of view verbally, in writing or by other means.	Constructivist	6,10,12
6	Observations and experiments are often designed specifically to address common physics misconceptions. For example, believing a heavier object will fall faster than a lighter object.	Constructivist	1,3

Table 3 Continued

7	The teacher acts as a facilitator, guiding students toward forming their own mental model of the observation or activity.	Constructivist	7,8,11
8	The teacher listens and uses student contributions whenever possible to build bridges to unfamiliar material.	Constructivist Change	4 2
9	The teacher uses discrepant events to place students in disequilibrium, intentionally setting up situations where what the students observe is in direct conflict with what they believe should happen.	Constructivist Change	1,3 5
10	When a concept has been thoroughly explored and discussed, the teacher provides opportunities for the student to apply the concept in a new way, or in a different context.	Constructivist	8,9
11	Whenever material is presented, the teacher uses examples and situations that their students can relate to.	Context Change	4,5 3,4
12	The teacher simplifies and “restricts the frame” when introducing new material, adding more real-life elements later on as the student understanding grows.	Context	3
13	The teacher takes the time to model for students how to recognize what is relevant and what is a distraction in a particular situation.	Change	7
14	When presenting material, the teacher uses multiple representations such as demonstrations, diagrams, graphs, equations, or other methods to convey the information.	Change	8
15	If the teacher uses multiple representations, they make sure to teach the students how to translate between the various representations (Shifting from a graph to an equation or from a sentence to a graph for example).	Change	9
16			

Table 3 Continued

17	Concepts are introduced multiple times, but with each new introduction, the context changes or more “real-life messiness” is added.	Change	10
18	The teacher has the student demonstrate their understanding of a particular concept using a variety of representations such as written words, graphs, demonstrations, or other methods.	Individuality	1,2,3,4,5,7,8
19		Individuality	6
		Social	6
	The teacher uses varied teaching methods to address students’ varied learning styles or multiple intelligences.	Learning	
20			7
		Individuality	
21	The teacher uses varied forms of assessment to accurately measure learning for students with different learning styles or multiple intelligences.		7,8
		Individuality	
22			8
	The teacher modifies lessons to respond to students’ diverse cultural backgrounds.	Individuality	
23			1
	The teacher modifies lessons to accommodate students whose primary language is not English.	Social	
		Learning	
24	The teacher modifies lessons to address students with special needs.		2,3
		Social	
		Learning	
25	Interaction between teacher and students is encouraged, and the students feel comfortable asking questions or discussing material with the teacher.		2,3
26		Social	4
	Exploration of course material occurs in an interactive group format, such as small or whole group discussions.	Learning	
27		Social	5
	The classroom atmosphere encourages group approaches to problem solving.	Learning	

Table 3 Continued

	The teacher is an active listener, guiding only when necessary as the students generate and explore ideas. The teacher has a framework in place to ensure that each member of the group is responsible for contributing to group products.	Social Learning	
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The respondents were asked to address the questions listed above in three ways. First, they were asked if the elements present in the survey item were present in their coursework while attending the UWRF physics teacher certification program. Second, they were asked the extent to which they valued the practices covered in the survey question. Third, they were asked how often they utilized the elements contained in the survey item in their own classrooms. Since a survey with predetermined questions has the possibility of “pigeon-holing” the respondent into a pre-determined category that may not be a perfect fit, it was decided that space would be provided to allow the respondent to explain in greater detail the reason for their item selection, or give them a chance to explain that none of the choices available adequately explained their situation (Patton, 2002).

Pilot Survey

In December of 2009, the survey was reviewed and piloted to ensure that the items accurately reflected Redish’s principles, that the items were easy for respondents to interpret, and that the format and length of the survey were acceptable. The pilot

participants consisted of a small focus group of teachers, as well as two university professors. The professors included Dr. Elisabeth Swanson, a science and education professor from Montana State University, and Dr. Eileen Korenic, a physics instructor and the director of the University of Wisconsin River Falls Summer Physics Program, which served as the context for this study. Dr. Korenic was chosen because of her extensive physics teaching experience, her experience as a secondary level teacher, and her knowledge of the UWRF program components. Dr. Swanson was chosen because of her extensive experience in science education research. Three of the focus group teachers were long-time master physics teachers. The master teachers were chosen because they all had at least 25 years of physics teaching experience, and they had earned numerous awards at both the state and national levels for exemplary physics teaching, and had been trained as and served as Physics Teacher Resource Agents (PTRA) and served in this role at various times in the UWRF program. Their knowledge and feedback proved invaluable during the piloting process. The researcher contacted the pilot participants via email. The email included a brief statement of the research study and contact information of the researcher. The actual interview questions can be found in appendix (##). The pilot interviews provided one level of feedback. Dr. Swanson, who reviewed and commented on the interview questions, provided an additional level. There were also two high school physics teachers with considerably less experience than the PTRA group. They were consulted to serve as more typical examples of the respondents for whom the survey was designed. Feedback from the pilot group was considered, and modifications to the survey questions being asked were made accordingly.

Survey Implementation

In February 2010, Dr. Korenic sent a letter to all participants who had ever been in the River Falls program dating back to its inception in 1986 seeking their willingness to participate in the survey. The invitation to participate in the survey went out to approximately 211 people. These people covered the entire spectrum of involvement with the Summer Physics Program. It was hoped that by reaching out to a wide variety of participants, a wide variety of perspectives and/or teaching situations and strategies would be revealed. The link to the survey was contained in this introductory letter. Based on survey responses, seven teachers were invited to serve as case study participants.

Analysis of the Survey Data

All of the survey responses were analyzed to create descriptive statistics revealing teachers' perceptions of their exposure in the UW-RF Summer Physics Program to teaching strategies aligned with Redish's five principles, the importance of the principles as determined by the teacher participants, and the degree to which the teachers incorporated the five principles in their science teaching practice.

At the end of each survey item, space was provided for free-form comments. These comments were analyzed qualitatively and provided detailed information to elaborate on the Likert scale prompts. This gave the participants the opportunity to explain in greater detail the ratings they gave each item with respect to their exposure to the practice, the level of importance they placed upon each practice, and their ability to

implement the practice in their own classrooms. As the free-form comments were examined, inductive analysis was used to search for patterns, themes, and relationships among what the participants believed they were being taught, what they felt was important, and what they actually brought into their classrooms (Patton, 2002).

Specifically, the free-form comments were read, reflective notes were made alongside the open-ended responses, and the data was coded with respect to which of the five principles was being addressed.

Case Studies

Merriam (2001) tells us “Case study is a particularly suitable design if you are interested in process (p.33).” She goes on to say that process involves such things as “describing the context and population of a study [and] discovering the extent to which a treatment or program has been implemented (p.33).” Bromley (1986) defines a case study as a means to get as close to the subject of interest as possible by both observing what occurs and probing for unseen, subjective factors such as thoughts or feelings which experiments and surveys are often not able to reveal (Merriam, 2001). Both Creswell (2007) and Merriam (2001) describe case study methodology as focusing on single units within a bounded system. For this study, physics teaching practices were being investigated with respect to Redish’s five principles. The UWRF Summer Physics Program served as the bounded system, and teacher-participants in the program served as the individual cases. Because it was believed the UWRF program attempted to instill within its participants certain aspects of these teaching practices, it was apparent that separating the phenomenon (the teaching practice) from the context (physics education

research in general and UWRF exposing the participants to these practices) would be difficult. In other words teaching does not occur in a vacuum, and it depends heavily upon context. Yin (1994) provides further support for the use of case study methodology in just such an instance by saying “A case study is an empirical inquiry that investigates a contemporary phenomenon within a real-life context, especially when the boundaries between phenomenon and context are not clearly evident (p.13) in Merriam (2001, p.27).”

Multiple sources of data collection were utilized in order to provide a rich description of what MacDonald and Walker (1977) called “the examination of an instance in action” (p.181) in Merriam (2001, p.29), and to look for any convergences in the findings. In addition, multiple cases were studied; each case was a participant in the UWRF Summer Physics Program, and each case study focused on this teachers thoughts and feelings about what teaching practices they felt they were exposed to in the UWRF program, the level of importance they placed on these practices, and the degree to which they were willing or able to carry these practices over into their classrooms. Seven cases were selected to focus on the aforementioned questions. Multiple cases were used with the intent of enhancing the external validity of the findings (Merriam, 2009). It was hoped that by observing multiple teacher-participants from the UWRF Summer Physics Program that a clearer picture of their exposure to, value of, and implementation of teaching practices related to the five principles could be revealed.

Case Participants

Purposeful sampling (Patton, 2002) was used to select teacher-participants from a variety of school districts. The participants were selected through maximum variation sampling. Maximum variation sampling, an example of purposeful sampling, involves selecting a wide range of variations, such as years of experience teaching physics, number of courses taken through the UWRF program, certification level, district size, socioeconomic makeup of the district in which the participant teaches, and the cultural makeup of the district in which the participant works. The years of experience of the case study participants ranged from six years to over 21 years in the classroom. Their school populations ranged from less than 200 students to approximately 1500 students. The percentage of students receiving free or reduced lunch ranged from 0-10% in one school to over 50% in two others. It was hoped that by choosing teachers with varying years of experience teaching in schools with widely different population sizes and demographics that trends among successful carry over practices for the teaching of physics could be observed in different teaching environments. It should also be noted that one of the participants had not, to date, actually taught physics. This participant taught primarily ninth grade physical science. In addition, another participant would not be teaching physics until the fall of 2010 when case study data collection was finished, and her first physics teaching assignment would be in a district where over 50% of the students were not native English speakers. Prior to this new assignment, the participant had taught physical science, biology, and other life sciences. It was hoped that utilizing this method of sampling, that the researcher could maximize the diversity available

within a relatively low survey response rate of about 26% (Cohen & Crabtree, 2009). The survey demographic data was analyzed, and seven participants were selected based on the aforementioned criteria for maximum variation sampling. All requirements were met for the protection of human subjects. This research study was approved by the Institutional Review Board of Montana State University. All case study participants agreed to be in the study and signed a letter of informed consent (see template Appendix ##). Additionally, all names and identifying information of the case participants were changed to protect their identities in the case narratives.

The Case Study Interview

Patton (2002) tells us “We interview people to find out from them those things we cannot directly observe” (p.340). Since it is impossible to observe things such as feelings, thoughts, or intentions, it is necessary to interview people to obtain this otherwise hidden information. It was hoped that information uncovered in the interview process would shed more light on what the participants felt were important components of the UWRF Summer Physics program. It was also hoped that the information would reveal what the participants felt were essential components of effective physics teaching, and what they were actually able to use from the UWRF program into their classrooms.

The UWRF Summer Physics participant interview questions were piloted with two science educators during the summer of 2010. One of them was a former participant in the UWRF program, while the other was a participant in an Environmental Education program at another Wisconsin university. The researcher contacted the pilot participants via email in July of 2010. The email included a brief statement of the research study and

contact information of the researcher. Modifications to the questions were made by the researcher after the first pilot interview to provide clarity for the participants of the questions being asked. These pilot interviews were recorded, transcribed, and reviewed by Dr. Elisabeth Swanson, a professor of science education at Montana State University. The actual interview questions can be found in appendix H. The pilot interviews provided one level of feedback. Dr. Swanson, who reviewed and commented on the interview questions, provided additional feedback.

To ensure that pertinent information was gathered while at the same time allowing the respondent some flexibility in their answers, an interview guide format was used. Patton (2002) defines the interview guide as a way for the interviewer to “remain free to build a conversation within a particular subject area, to word questions spontaneously, and to establish a conversational style [while] focus[ing] on a particular subject that has been predetermined” (p.343). Unlike the more unstructured informal conversational interview or the tightly controlled standardized open ended interview, it was hoped that using the interview guide protocol would serve as a middle of the road approach that would introduce some degree of structure, but also allow considerable freedom for the respondents within that structure.

The interview questions were separated into three groups. The first five questions focused on the participant’s background, prior knowledge of physics, confidence level in teaching ability, and reasons for entering the UWRF Summer Physics program. The following five questions focused on what the participant was willing/able to use from the program with respect to their classroom practice, and what the participant might be doing

in their classroom that was not part of the program. In other words, these questions were focused on degree of usefulness the program provided for the participant. The remaining seven questions focused on actual classroom practices and feelings the participant may have about the resources they have available, and how effective they feel their teaching has been for their students. The final question asks the participant to provide any additional information that may have been missed during the interview. This open-ended question gives the respondent the opportunity to fill in any gaps or provide any other information they feel is important.

The final seven questions tie closely with the Physics Teacher Survey previously mentioned. It was the intention of this group of interview questions to allow the participants the opportunity to explain specific beliefs and practices that occur within their classrooms.

Throughout the summer and early fall of 2010, the seven interviews were conducted. The first interview was conducted in person, while the remaining six were conducted by telephone, due to the large distances between myself and the case study participants.

This information, combined with the data acquired from the aforementioned survey, as well as the portfolio examination served as multiple sources of data to be used for triangulation purposes to paint a clearer picture as to what these participants felt was important to the teaching of physics, what they learned from their exposure to the UWRF Summer Physics program, and what they actually use in their respective classrooms.

The interview questions can be found in appendix H.

The Portfolio

Often what we think we are doing or accomplishing in the classroom can be better, worse, or simply different than what actually occurs. It is for this reason it was deemed necessary to obtain teacher artifacts in the form of a portfolio to help substantiate survey choices and interview responses. Patton (2002) tells us that documentation through portfolios paints a more accurate picture of occurrences in the classroom than does relying solely on standardized survey responses. Indeed, in a research study on portfolios, Harrison, Hofstein, Eylon, & Simon (2008) found that continuing professional development programs that required participants to create a collection of artifacts that show evidence of teacher work and student learning helped teachers gain insights and evaluate whether pre-determined goals were being met. In addition, in a case study exploring the impacts on teachers of portfolio analysis, Dinham & Scott (2003) found that “The teaching portfolio performs the function of demonstrating one’s capabilities and accomplishments achieved through documents, artifacts and empirical evidence, judiciously selected and linked together in a theoretically sound and coherent fashion” (p. 231).

Since a component of this study was to look for evidence of the five principles laid out by Redish (constructivism, context, change, individuality, and social learning) in UWRF summer physics program participants’ classrooms, as well as evidence of carry-over of specific teaching strategies or content presented in the UWRF program, the portfolio guidelines were naturally directed toward the Redish principles, yet were broad enough that other practices might surface too. Though it is unlikely that every Redish

principle would be visible in a single portfolio artifact, it was hoped that the lessons and other items provided would shed light on the importance each teacher placed on given principles, and what teachers were able to use as a result of their participation in the UWRF program.

The artifacts requested included narrative statements of teaching goals and philosophies, lesson plans, student work samples, lab exercises, examples of student lab reports, assessments, examples of student work on science assessments, and any special projects that occur during the year. In order to foster a feeling of ownership and creativity, the teachers were allowed to select the topics for which they submitted information, but in order to maintain consistency across cases, they were each asked to submit information of a specific type (Zeichner & Wray, 2001). Each portfolio entry contained the following items for one lesson chosen by the teacher:

1. A cover page with a brief overview of the lesson and the intended outcomes.
2. Additional materials revealing the learning design such as lesson plans, laboratory protocols, handouts, materials generated in class, media such as PowerPoint, Vernier or PASCO generated materials, etc.
3. Two or three student work samples from the lesson that are part of the instruction such as homework assignments, tests or quizzes, lab reports, projects, journal entries, video data of classroom presentations, etc.
4. A reflection page for each student work sample.
5. An overall reflection about the teacher's portfolio entry and teaching.

6. A reflection about what the teacher learned in the UWRF Summer Physics program, emphasizing connections to the lessons they provided for the portfolio.

The portfolio request can be found in appendix J.

Data Collection

Multiple sources of data were collected from multiple cases to strengthen the validity of the study (Merriam, 2009). Data obtained from the survey, open-ended comments, interviews, and portfolio submissions were analyzed and triangulated. For example, the researcher checked to see if the item selected on the survey matched with free-form comments made by the participant, was evident in the portfolio materials examined, and was discussed during the interview process. When multiple sources of data pointed toward the same answer, this triangulation enhanced the credibility of the study (Patton, 2002). Further, when similar themes emerged among multiple cases, this could be interpreted as increasing the validity of the answer to questions of what the participants felt they were exposed to in terms of physics teaching practices, and what they felt they were willing or able to use in their classrooms as a result of that exposure (Merriam, 2009).

In late February 2010, a link to an online survey was sent to Dr. Eileen Korenic, the director of the UWRF Summer Physics Program. She then disseminated the link, along with a letter of introduction to each of the participants in the program. One of the survey questions asked the participants for permission to be contacted by the researcher. This gave participants the option of being able to participate in the survey, yet remain

completely anonymous to the researcher. Survey items were analyzed, particularly the free-form comment sections. From the survey responses and free form comments, seven respondents were invited to serve as case study participants for this study.

From July until October 2010, the seven case study participants were interviewed. Each interview was recorded and transcribed in its entirety in the fall of 2010. As the interview data were compared across cases, notes were made, and common themes were noted. It was with these themes that the researcher attempted to determine 1) What the participant felt they were exposed to in the River Falls program with respect to the Five Principles, 2) What value the participants places on physics teaching techniques they were exposed to while in the River Falls program, and 3) Which techniques were carried over into the classrooms of the participants and to what extent. The complete transcriptions of the interviews can be found in Appendix I.

Finally, for the third source of data, each case participant created a portfolio which contained specific lessons they utilized in their classrooms that they felt addressed aspects of the five principles. The lessons consisted of lecture notes, assignments, lab activities, projects, and/or exams given by the teacher. The portfolio gave the researcher the opportunity to triangulate what the teacher indicated on the survey, what was observed in their classroom, and what was actually “on paper” within the portfolio (Merriam, 2009). See Appendix J for the Science Lessons Portfolio. Each activity contained within the unit submitted was analyzed for adherence to each aspect of the five principles as explained in Chapter 2. The portfolios were collected from October – December 2010.

Data Analysis

The case studies were constructed based on the procedures suggested by Creswell (2007) and Patton (2002). Creswell defines case study research as "...a qualitative approach in which the investigator explores a bounded system... over time through detailed, in-depth data collection involving multiple sources of information, and reports a case description and case-based themes" (2007, p. 73). In this study, methods of teaching physics were investigated within the bounded system of the UWRF Summer Physics Program. Initially, seven participants were invited to serve as case study participants. The raw case data was assembled, a case record was constructed, and a final case paper copies were also created. The data was condensed into a case record for each individual case. This process narrative was written (Patton, 2002). Initial analysis of the case data from survey responses, free-form comments, portfolio inspection, and interviews was conducted, and themes, patterns, and categories were identified both within and across cases through this triangulation (Merriam, 2001).

The raw case data consisted of survey responses, free-form comments, interview and portfolio data. All data was saved electronically and involved editing, eliminating redundancies, fitting parts together, and organizing the information chronologically (Patton, 2002). For this study, each case was analyzed separately and the data was organized categorically based upon the five principles (Constructivist, Context, Change, Individuality, and Social Learning). As the case study data was analyzed, items of interest with respect to the five principles were noted using open coding (Merriam, 2009). Later, as common themes began to emerge from the open coding process, the list of notes

was condensed into categories (Merriam, 2009; Creswell, 2007). Unusual or insightful quotes and field notes were tagged for use in the case narratives.

A case narrative should “afford the reader the vicarious experience of having been there” (Merriam, 2001, p. 238). Merriam goes on to say that a detailed description of the events and context being investigated is needed for the reader to “assess the evidence upon which the researcher’s analysis is based (p.238). As such, a preliminary case narrative was created after collecting, inductively analyzing (Merriam, 2009), and consolidating the data from surveys, free-form comments, portfolios, and interviews.

A cross-case analysis (Merriam, 2009) was conducted, and patterns and themes related to the exposure to, belief in, and implementation of aspects of the five principles were inductively created (Patton, 2002) across cases. Both similarities and differences emerged in each of the three aforementioned strands with respect to each of the five principles. From this cross-case analysis, a picture began to emerge about what participants in the Summer Physics Program at UWRF felt they were exposed to with respect to the five principles, which aspects of the five principles the participants felt were important, and also, which aspects they were actually able to implement within their own classrooms. See chapter 4 for the individual case narratives and the findings of the cross-case analysis.

Study Quality

According to Patton (2002) “The logic of triangulation is based on the premise that no single method ever adequately solves the problem of rival explanations. Because each method reveals different aspects of empirical reality, multiple methods of data

collection and analysis provide more grist for the research mill” (p.555-556). It was for this reason that both quantitative data in the form of a survey, as well as qualitative data in the form of free-form responses, interviews, portfolios, and classroom observations were comparatively analyzed against each other (Patton, 2002). The survey provided descriptive statistics on the nature of the district that the participants worked in. It also gave the participant Likert-Scale choices to rate the degree to which they felt familiar with a particular teaching principle, the importance they placed on that principle, and the degree to which they actually utilized the principle in their classroom. However, the quantitative information contained in the survey focused on aspects of physics teaching pre-determined by myself, and the physics education research literature, and as such it may have provided a biased representation of participants beliefs and actual teaching practices. The previously mentioned qualitative data gave the participants the opportunity to elaborate on their survey choices, provide evidence to support (or refute) their choices through the contents of their portfolios and finally, to tell their story through direct interviews. This methodological triangulation (Patton, 2002) was used in a complementary fashion to provide a richer and more thorough picture of the beliefs and practices of teachers who have been a part of the Summer Physics Program at UW-River Falls. It was hoped that utilizing both quantitative and qualitative methods would uncover convergence, which would increase researcher confidence in the findings, as well as reveal areas of divergence, which could bring to light the complex nature of physics teaching in the high school classroom and suggest ideas for future study. Triangulation within the various qualitative data sources was also undertaken by cross

checking the comments with the interviews, and with the information contained within the portfolios (Patton, 2002). Theory triangulation consisted of comparing survey and case study findings to findings in the physics education research literature found in Chapter 2.

Content validity for the survey was enhanced by first soliciting expert feedback during the design process and by then piloting the survey. Because the survey was sent to all UWRF Summer Physics Program participants and they had the choice as to whether or not to participate in the study, sampling error was a potential concern.

Credibility of the qualitative findings was established by having the case study participants review the interpretations of the researcher with respect to the presence of the five principles within the various forms of qualitative data studied (Creswell, 2007). A rough draft of the case narrative was presented to each case study participant in November of 2010, and they were asked to review it for accuracy and to elaborate or provide further information as necessary. The narratives were then edited accordingly. Samples of free-form comments, interviews, and portions of portfolio artifacts were included in the final case narratives so as to provide the reader with the data from which the interpretations arose (Lincoln & Guba, 1985 in Creswell, 2007).

Potential Limitations of the Study

Though measures were taken to maximize the quality of this study, there are several limitations present nonetheless. First of all, this study was used to investigate physics teaching practices occurring in the high school setting. The context of the study was limited to participants in the UW-River Falls Summer Physics Program, therefore

sampling was limited to a select group of teachers. Participation in the survey was voluntary, and the researcher was not able to obtain participant contact information unless the participant provided it. This limited the sample to those teachers readily willing to participate further in the study, and may have skewed results and interpretations toward adherence to the five principles. In other words, if there was a 100% response rate the survey results may have looked different. In addition, if the researcher had the opportunity to contact any of the participants instead of only those who were willing to provide contact information, the portfolio data and classroom observations may have looked different as well. Because of this, care must be taken in generalizing the results of this study. The participants were all part of one specific program, and their willingness to participate further in the study may indicate that their interest in pursuing varying teaching strategies for high school physics is stronger than is true for the average high school physics teacher.

Researcher Perspective

In any research involving qualitative methods one cannot escape the fact that “the researcher is the primary instrument for data collection and analysis” (Merriam, 2009, p.15). As such, it is important for the researcher to put forth personal information that allows the reader to better understand the researcher’s interpretation of the data. Merriam (2009) goes on to say that rather than trying to eliminate biases possessed by the researcher, it is more important to monitor them regarding how they may be “shaping the collection and interpretation of the data” (p.15). Both my experiences as a physics teacher and as a three-year student of the River Falls Summer Physics Program have no

doubt shaped the perspectives I have brought to this study, and I have described those experiences here. I have taught physics (among other subjects) for nearly fifteen years. I say nearly, because I did not begin my career in physics. I began as a chemistry and general science teacher in the Peace Corps, and continued that track upon returning to the United States. During my first year of teaching in the US at a small school in rural Wisconsin, I was thrust into the role of physics teacher with about 24 hours notice in late November. This “trial by fire” taught me two things almost immediately. I learned that I loved physics, and also that I had absolutely no idea how to teach it. To address my shortcomings as a physics teacher, I found a program that claimed that over the course of several summers, I could earn state certification in physics, and more important, I could learn how better to teach the subject. That program was the UW-River Falls Summer Physics Program previously mentioned. As a graduate of their Master of Science Education-Physics program, I have since continued to teach physics in the state of Wisconsin. My three years of intense experience with the UWRF program made it a logical choice to serve as the context for this study. By having taken the same courses as the participants while I was myself a participant, I have “walked in their shoes” so to speak. The longer I stay in the field of physics education, the more I realize that, though mastery of content is important, there is much more to learn about being an effective physics teacher. For me, what started out as a survival mechanism to master just enough content to stay a day or two ahead of the students, has evolved into a desire to seek out the most effective methods of delivery of that content. That was the purpose of this study. I wanted to explore research-based physics teaching strategies being used by

various universities to train secondary school physics teachers. I wanted to see what they entailed, and wanted to explore the research base upon which they had been built. Also, I wanted to talk to other participants to find out what they thought of their experience in the UWRF program. I wanted to learn more about their teaching methods, and find out how much of what they had learned actually carried over into their classrooms. I wanted to hear what these teachers had to say about their experiences, and gather information they had acquired as they worked with their own students. What worked well for them? What did they perceive as obstacles to their ability to teach at the highest level? What changes would they like to see and on what scale would these changes need to be made? These were some of the questions I attempted to answer.

CHAPTER 4

RESULTS OF THIS STUDY

Introduction

This chapter presents the results of the analysis of data collected in this mixed methods study. In keeping with the order of the discussion of the data collection and analysis procedures in Chapter 3, the following results are presented and discussed in these five sections:

1. The University of Wisconsin – River Falls Summer Physics Program Survey.
2. Summary of the University of Wisconsin – River Falls Summer Physics Program Survey.
3. Case Studies of the UWRF Summer Physics Program Participants.
4. Summary of Case Studies.
5. Summary of Overall Findings.

A brief, explanatory introduction is given at the start of each section, followed by a presentation and discussion of the results, and concludes with a brief summary of the results obtained in that specific area of the study. The final section provides an overall summary of all of the findings.

The University of Wisconsin – River
Falls Summer Physics Program Survey

This section describes the results of the analysis of the UWRF Summer Physics Program Survey, which can be found in Appendix _____. The survey was designed to assess the ways in which the UWRF Summer Physics Program assisted high school physics teachers in providing physics instruction to students in grades 9-12. Specifically, this survey was designed to answer the following research questions:

Research Question 2: What aspects of a program specifically designed to develop physics teachers' knowledge of physics content and pedagogical skills were present in the target program in this study?

Research Question 3: What aspects of a program specifically designed to develop physics teachers' content knowledge and pedagogical skills were viewed as important or useful by participants?

Research Question 4: What aspects of a program specifically designed to further physics teachers' practices were used in the classrooms of participants?

There were 54 participant surveys returned out of a possible 211 participants contacted by UWRF, and re-contacted up to two additional times if the survey was not initially returned. This corresponds to a response rate of approximately 26% of the participants in the program dating back to its inception in 1986.

Section I UWRF Summer Physics Training Program Survey

The results of section I are summarized in Table 4 below (N=54).

Table 4. Demographic results for survey respondents in the River Falls Summer Physics Teacher Training Program.

Demographics Question	Choices	N	%	Average	σ
1. How many years have you taught?	1: 1 st year 2: 2-5 years 3: 6-10 years 4: 11-15 years 5: 16-20 years 6: 21+ years	0 7 16 16 6 9	0 13.0 29.6 29.6 11.1 16.7	Choice 3.88	1.27
2. What percentage of students in your building are eligible for free or reduced lunch?	1. 0-10% 2. 11-20% 3. 21-30% 4. 31-40% 5. 41-50% 6. Over 50%	11 15 12 5 4 7	20.4 27.8 22.2 9.3 7.4 13.0	Choice 2.94	1.64
3. How would you describe the school in which you teach in terms of student population?	1. 200 or less 2. 201-400 3. 401-600 4. 601-800 5. 801-1000 6. 1001-1500 7. 1501-2000 8. Over 2000	3 9 11 6 2 13 9 1	5.6 16.7 20.4 11.1 3.7 24.1 16.7 1.9	Choice 4.39	2.02
4. What percentage of the students in your class are not Caucasian?	1. 0-10% 2. 11-20% 3. 21-30% 4. 31-40% 5. 41-50% 6. 51-60% 7. 61-70% 8. 71-80% 9. 81-90% 10. 91-100%	39 3 7 1 1 2 0 1 0 0	72.2 5.6 13.0 1.9 1.9 3.7 0 1.9 0 0	Choice 1.76	1.53
5. What percentage of your students are male? What percentage of your students are female?	Male Female		50.8 49.2		
6. What percentage of students in your class have limited English proficiency?	1. 0-10% 2. 11-20% 3. 21-30% 4. 31-40% 5. 41-50% 6. Over 50%	51 1 2 0 0 0	94.4 1.9 3.7 0 0 0	Choice 1.09	0.40
7. How would you compare the achievement level of your students to that of other students in your state?	1. Far below 2. Below 3. About the same 4. Above 5. Far above	1 5 22 22 4	1.9 9.3 40.7 40.7 7.5	Choice 3.43	0.84

Table 4 Continued

8. Please indicate which course(s) you have taken in the UW-RF program.	Mechanics	39	79.6		
	Electricity & Magnetism	45	86.5		
	Modern Physics	36	70.6		
	Astronomy	20	43.5		
	Astrophysics	14	30.4		
	Acoustics	25	54.3		
	Optics	30	62.5		
	Laser Physics	12	27.3		
	Thermodynamics	19	39.1		
	Use of Physics Equipment/Technology in the classroom	14	32.6		
	Modeling	20	43.5		
9. What were your reasons for entering the program? (Check all that apply).	1. General interest	23	42.6		
	2. To maintain state licensure	21	38.9		
	3. To gain physics licensure	20	37.0		
	4. To Earn MSE-Physics degree	41	75.9		
10. What is your current status in terms of physics teaching?	1. Not certified, do not intend to become certified.	6	11.1		
	2. Not certified, intend to become certified.	9	16.7		
	3. Physics certified, not seeking MSE-Physics degree.	9	13.0		
	4. Physics certified, seeking MSE-Physics degree.	8	14.8		
	5. Physics certified with MSE-Physics degree.	24	44.4		
11. When did you take your most recent UWRF physics course?	1. pre-2001	4	7.4	Choice 7.02	2.81
	2. 2001	0	0		
	3. 2002	3	5.6		
	4. 2003	4	7.4		
	5. 2004	6	11.1		
	6. 2005	6	11.1		
	7. 2006	3	5.6		
	8. 2007	9	16.7		
	9. 2008	6	11.1		
	10. 2009	15	27.8		

The purpose of this section of the survey was to gather background, demographic, and contextual information about the participants. The largest percentage of respondents, 27.9%, indicated they had taken their most recent UWRF Summer Physics course in 2009. A total of 72.3% of the participants had taken at least one course since 2005, while only 7.4% of them indicated their last course was taken before 2001. This indicated that

a majority of the survey respondents were either still in the program, or had taken classes very recently.

Respondents were also asked about their years of teaching experience. Fully 87% of them indicated they had taught for at least six years, with 27.8% of them having at least 16 years of experience. None of the respondents were first year teachers, and 13% of them had taught for less than five years.

When asked about their current status with respect to physics teaching, 44.4% of the respondents indicated they were physics certified and had earned a Master of Science-Education (MSE) degree. In all, 14.8% were physics certified, and intending to complete their MSE degree, and total of 13.0% were certified, but not seeking an MSE degree. In addition, 27.8% of the respondents were not physics certified, with 16.7% intending to become certified, and 11.1% not intending to do so.

In examining the courses taken by the respondents, 79.6% indicated they had taken Mechanics, 86.5% had taken Electricity and Magnetism, and 70.6% had taken Modern Physics. A probable explanation for the higher enrollments in these three courses is that they are considered core courses in the program, and all of them must be taken to complete the program. Other courses, such as optics, thermodynamics, acoustics, and laser physics, are considered second tier courses, and are purely elective in nature. Laser physics had the lowest enrollment among respondents at 27.3%, whereas Electricity and Magnetism had the highest at 86.5%. It should be noted that the Laser Physics course was only taught once, the summer of 2004.

When asked what their reasons were for entering the program, 75.9% of the respondents indicated they had originally joined to earn an MSE degree, while 38.9% wanted to maintain their state licensure, and 37.0% were trying to gain physics certification. In addition, 42.6% stated that general interest was one of the reasons for their enrolling. Respondents could check more than one choice for this item.

The respondents were also asked to provide demographic information about the schools they taught in. In terms of school population size, 42.7% of the respondents taught in a grade 9-12 school of at least 1001 students, 37.1% of the respondents taught at schools between 201-600 students, 5.6% worked in schools of less than 200, and 1.9% were on the other extreme, working in schools of over 2000 students.

In terms of students being eligible for free and reduced lunch, an indicator of student socioeconomic status, 20.4% of the respondents said that less than 10% of their students met eligibility requirements, while 13.0% said that over 50% of their students were eligible. The largest percentage, 27.8%, of respondents noted that 11-20% of their students were eligible for free and reduced lunch. Since many students don't enroll in advanced science courses taught by some respondents, had the survey question asked about free and reduced eligibility for each teacher's school as a whole, not just those enrolled in courses taught by the instructor, it is likely that the eligibility figures would have been higher.

With regard to student ethnicity, 72.2% of the respondents indicated the student population was at least 90% Caucasian, while 5.6% reported that their student population was less than 50% Caucasian, and no respondent indicated less than 30% Caucasian

students for this item. Regarding gender, respondents reported that 50.8% of their students were male, while 49.2% were female. Regarding students' English proficiency, 94.4% of the respondents reported that less than 10% had limited proficiency, and 3.7% stated that 21-30% of their students had limited proficiency.

Of the 54 respondents, 88.9% felt the achievement level of their students was about the same or better than similar students throughout the state where they taught, while 7.5% felt their students were far above comparable students within the state where they taught, and 1.9% reported they felt their students' achievement levels were far below those in the state in which they taught.

Section II UWRF Summer Physics Training Program Survey

The purpose of section II of the survey was to gather information concerning physics teaching practices aligned with Redish's five principles. Each of the first 27 questions in this section focused on one or more of the Five Principles proposed by Redish and reviewed in Chapter 2 of this dissertation. The respondents were asked to rank each question in three ways. First, they were asked to indicate whether a particular teaching approach occurred during their training in the UWRF Summer Physics Program and with what frequency (corresponding to Research Question 2). Second, the respondents were asked to indicate how much they valued each teaching approach (Research Question 3), and third, they were asked about the frequency with which they use that particular teaching practice in their own classroom (Research Question 4). Appendix E indicates which of the Redish Principles are being addressed with each question. Note that there are instances where a given physics teaching practice

incorporates elements of more than one of Redish's five principles. Thus certain items in Section II are used as indicators of more than one principle.

In Section II, the questions were assessed using a five point Likert scale with the value of 1 representing Not at All, and a value of 5 representing To a Great Extent for questions 1-27. There was also a choice 6, which was reserved for Don't Know. It should be noted that choice 6 was not included when averages and standard deviations were calculated for the responses, as it does not fall within the continuum of Not at All – To a great Extent. This alternative simply gave the respondents a way to indicate that the question did not apply or did not make sense to them. In addition, an open response comment space was provided so that the respondent could elaborate on their answer if they chose to. Two final questions asked about the willingness of the respondent to participate further in this study (question 28) and, if the response was positive, to provide contact information to the researcher (question 29).

Table 5 provides the number and percentage of respondents choosing each response category for each item, as well as the mean and standard deviation.

A total of 54 teachers responded to the survey, although occasionally the number of responses is lower because of missing data. In the table below, the first column indicates which Redish principle is being addressed. The next column shows the survey question. The next column indicates a 2, 3, or 4, corresponding to research question two, three, and four, respectively. The following columns display descriptive statistics including mean, standard deviation, and a disaggregation of the number of responses for each choice on the Likert scale.

Table 5. Survey results with respect to Redish principles and occurrence, value, and use in the classroom.

Principle	Question & Strand 2 = Happened during UWRF training 3= Value this approach to teaching a lesson 4 = Use this approach in own classroom		M	SD	Not at All 1	2	3	4	To a great extent 5
					n (%)	n (%)	n (%)	n (%)	n (%)
Constrv Context Change Individ Soc Learn	1. When a new topic is introduced, the teacher provides some form of engagement to arouse the curiosity of the student such as a demonstration, a thought provoking question, or a classroom discussion.	2	4.04	0.92	0 (0%)	2 (3.7%)	15 (27.8%)	15 (27.8%)	21 (38.9%)
		3	4.70	0.54	0 (0)	0 (0)	2 (3.7)	12 (22.2)	38 (72.2)
		4	4.26	.68	0 (0)	0 (0)	7 (13.0)	25 (46.3)	21 (38.9)
Constrv Change	2. When a new topic is introduced, the teacher assesses students' prior knowledge to modify instruction.	2	2.85	1.16	4 (7.4)	20 (37.0)	15 (27.8)	6 (11.1)	7 (13.0)
		3	4.04	0.95	1 (1.9)	1 (1.9)	14 (25.9)	17 (31.5)	21 (38.9)
		4	3.57	1.09	2 (3.7)	6 (11.1)	18 (33.3)	15 (27.8)	13 (24.1)
Constrv	3. Students explore concepts by gathering data and searching for patterns or relationships.	2	4.23	0.87	0 (0)	2 (3.7)	9 (16.7)	17 (31.5)	25 (46.3)
		3	4.61	0.71	0 (0)	2 (3.7)	1 (1.9)	13 (24.1)	38 (70.4)
		4	4.35	0.83	0 (0)	1 (1.9)	9 (16.7)	14 (25.9)	30 (55.6)

Constrv	4. The students are encouraged to explain observations in their own words verbally, in writing or by other means.	2	3.92	0.97	0 (0)	4 (7.4)	14 (25.9)	16 (29.6)	18 (33.3)
		3	4.52	0.77	0 (0)	1 (1.9)	6 (11.1)	11 (20.4)	36 (66.7)
		4	4.28	0.98	0 (0)	4 (7.4)	8 (14.8)	11 (20.4)	31 (57.4)
Constrv	5. The students are encouraged to justify or defend their points of view verbally, in writing or by other means.	2	3.74	1.02	0 (0)	9 (16.7)	9 (16.7)	22 (40.7)	13 (24.1)
		3	4.28	0.79	0 (0)	2 (3.7)	5 (9.3)	23 (42.6)	24 (44.4)
		4	4.00	0.97	0 (0)	5 (9.3)	10 (18.5)	19 (35.2)	20 (37.0)
Constrv	6. Observations & experiments are often designed specifically to address common physics misconceptions. For example, believing a heavier object will fall faster than a lighter object.	2	3.92	0.84	0 (0)	1 (1.9)	17 (31.5)	19 (35.2)	15 (27.8)
		3	4.41	0.71	0 (0)	1 (1.9)	4 (7.4)	21 (38.9)	28 (51.9)
		4	4.17	0.84	1 (1.9)	0 (0)	9 (16.7)	23 (42.6)	21 (38.9)
Constrv	7. The teacher acts as a facilitator, guiding students toward forming their own mental models of the observation or activity.	2	3.56	1.02	0 (0)	9 (16.7)	18 (33.3)	15 (27.8)	12 (22.2)
		3	4.20	0.88	0 (0)	3 (5.6)	7 (13.0)	20 (37.0)	24 (44.4)
		4	3.76	0.90	0 (0)	4 (7.4)	18 (33.3)	18 (33.3)	13 (24.1)
Constrv Change	8. The teacher listens and uses student contributions whenever possible to build bridges to unfamiliar material.	2	3.82	0.99	0 (0)	5 (9.3)	17 (31.5)	15 (27.8)	17 (31.5)
		3	4.39	0.76	0 (0)	1 (1.9)	6 (11.1)	18 (33.3)	29 (53.7)
		4	4.09	1.78	0 (0)	2 (3.7)	8 (14.8)	27 (50.0)	17 (31.5)

Constrv Change	9. The teacher uses discrepant events to place students in disequilibrium, intentionally setting up situations where what the students observe is in direct conflict with what they believe should happen.	2	3.36	1.05	1 (1.9)	8 (14.8)	23 (42.6)	8 (14.8)	10 (18.5)
		3	3.86	1.08	1 (1.9)	6 (11.1)	10 (18.5)	18 (33.3)	18 (33.3)
		4	3.33	1.03	3 (5.6)	7 (13.0)	19 (35.2)	19 (35.2)	6 (11.1)
Constrv	10. When a concept has been thoroughly explored and discussed, the teacher provides opportunities for the student to apply the concept in a new way, or in a different context.	2	3.65	1.01	0 (0)	7 (13.0)	17 (31.5)	15 (27.8)	13 (24.1)
		3	4.30	0.77	0 (0)	1 (1.9)	7 (13.0)	21 (38.9)	25 (46.3)
		4	3.82	0.92	0 (0)	4 (7.4)	16 (29.6)	20 (37.0)	14 (25.9)
Context	11. Whenever material is presented, the teacher uses examples and situations that their students can relate to.	2	4.41	0.69	0 (0)	0 (0)	6 (11.1)	20 (37.0)	28 (51.9)
		3	4.82	0.39	0 (0)	0 (0)	0 (0)	10 (18.5)	44 (81.5)
		4	4.59	0.66	0 (0)	0 (0)	5 (9.3)	12 (22.2)	37 (68.5)
Context	12. The teacher simplifies and “restricts the frame” when introducing new material, adding more real-life elements later on as student understanding grows.	2	3.75	1.03	0 (0)	6 (11.1)	14 (25.9)	13 (24.1)	14 (25.9)
		3	4.14	0.90	0 (0)	3 (5.6)	8 (14.8)	18 (33.3)	21 (38.9)
		4	4.02	0.98	0 (0)	4 (7.4)	11 (20.4)	15 (27.8)	20 (37.0)
Context	13. The teacher takes the time to model for students how to recognize what is relevant and what is a distraction in a particular situation.	2	3.51	1.08	2 (3.7)	6 (11.1)	14 (25.9)	16 (29.6)	9 (16.7)
		3	4.04	0.90	1 (1.9)	1 (1.9)	10 (18.5)	21 (38.9)	17 (31.5)
		4	3.84	0.96	1 (1.9)	2 (3.7)	15 (27.8)	18 (33.3)	14 (25.9)

Change	14. When presenting material, the teacher uses multiple representations such as demonstrations, diagrams, graphs, equations, or other methods to convey the information.	2	4.40	0.86	0 (0)	3 (5.6)	4 (7.4)	15 (27.8)	31 (57.4)
		3	4.72	0.45	0 (0)	0 (0)	0 (0)	15 (27.8)	39 (72.2)
		4	4.52	0.64	0 (0)	0 (0)	4 (7.4)	18 (33.3)	32 (59.3)
Change	15. If using multiple representations, the teacher makes sure to teach the students how to translate between the various representations (Shifting from a graph to an equation or from a sentence to a graph for example).	2	4.00	0.99	1 (1.9)	1 (1.9)	16 (29.6)	13 (24.1)	21 (38.9)
		3	4.47	0.64	0 (0)	0 (0)	4 (7.4)	20 (37.0)	29 (53.7)
		4	4.28	0.69	0 (0)	0 (0)	7 (13.0)	24 (44.4)	22 (40.7)
Change	16. Concepts are introduced multiple times, but with each new introduction, the context changes or more “real-life messiness” is added.	2	3.47	0.99	1 (1.9)	7 (13.0)	18 (33.3)	17 (31.5)	8 (14.8)
		3	3.87	0.92	0 (0)	3 (5.6)	17 (31.5)	17 (31.5)	16 (29.6)
		4	3.64	0.86	0 (0)	4 (7.4)	20 (37.0)	20 (37.0)	9 (16.7)
Change	17. The teacher has students demonstrate their understanding of a particular concept using a variety of representations such as written words, graphs, demonstrations, or other methods.	2	3.89	1.05	0 (0)	7 (13.0)	11 (20.4)	16 (29.6)	19 (35.2)
		3	4.39	0.76	0 (0)	1 (1.9)	6 (11.1)	18 (33.3)	29 (53.7)
		4	4.19	0.78	0 (0)	1 (1.9)	9 (16.7)	23 (42.6)	21 (38.9)
Individlty	18. The teacher uses varied teaching methods to address students’ varied learning styles or multiple	2	3.31	1.16	3 (5.6)	11 (20.4)	14 (25.9)	15 (27.8)	9 (16.7)
		3	4.33	0.84	0 (0)	2 (3.7)	7 (13.0)	17 (31.5)	28 (51.9)

	intelligences.	4	4.04	0.91	0 (0)	4 (7.4)	9 (16.7)	22 (40.7)	19 (35.2)
Individlty Soc Learn	19. The teacher uses varied forms of assessment to accurately measure learning for students with different learning styles or multiple intelligences.	2	2.77	1.03	6 (11.1)	16 (29.6)	16 (29.6)	14 (25.9)	1 (1.9)
		3	3.96	0.89	0 (0)	4 (7.4)	10 (18.5)	24 (44.4)	16 (29.6)
		4	3.57	0.89	0 (0)	7 (13.0)	14 (25.9)	28 (51.9)	5 (9.3)
Individlty	20. The teacher modifies lessons to respond to students' diverse cultural backgrounds.	2	1.98	0.85	14 (25.9)	15 (27.8)	11 (20.4)	1 (1.9)	0 (0)
		3	3.19	1.08	2 (3.7)	13 (24.1)	18 (33.3)	13 (24.1)	7 (11.1)
		4	2.65	1.00	5 (9.3)	20 (37.0)	16 (29.6)	8 (14.8)	2 (3.7)
Individlty	21. The teacher modifies lessons to accommodate students whose primary language is not English.	2	1.22	0.58	23 (42.6)	2 (3.7)	2 (3.7)	0 (0)	0 (0)
		3	3.45	1.26	4 (7.4)	8 (14.8)	11 (20.4)	14 (25.9)	12 (22.2)
		4	3.45	1.26	8 (14.8)	13 (24.1)	14 (25.9)	9 (16.7)	4 (7.4)
Individlty	22. The teacher modifies lessons to address students with special needs.	2	1.97	1.05	12 (22.2)	9 (16.7)	6 (11.1)	1 (1.9)	1 (1.9)
		3	3.96	0.97	0 (0)	4 (7.4)	13 (24.1)	16 (29.6)	19 (35.2)
		4	3.71	1.05	1 (1.9)	7 (13.0)	11 (20.4)	20 (37.0)	13 (24.1)
Soc Learn	23. Interaction between teacher and students is encouraged, and the students feel comfortable asking	2	4.70	0.63	0 (0)	0 (0)	5 (9.3)	6 (11.1)	43 (79.6)
		3	4.89	0.32	0 (0)	0 (0)	0 (0)	6 (11.1)	48 (88.9)

	questions or discussing material with the teacher.	4	4.80	0.45	0 (0)	0 (0)	1 (1.9)	9 (16.7)	44 (81.5)
Soc Learn	24. Exploration of course material occurs in an interactive group format, such as small or whole group discussion.	2	4.13	0.95	0 (0)	3 (5.6)	12 (22.2)	14 (25.9)	25 (46.3)
		3	4.50	0.69	0 (0)	1 (1.9)	3 (5.6)	18 (33.3)	32 (59.3)
		4	4.28	0.90	0 (0)	3 (5.6)	7 (13.0)	16 (9.6)	28 (51.9)
Soc Learn	25. The classroom atmosphere encourages group approaches to problem solving.	2	4.19	0.99	0 (0)	4 (7.4)	10 (18.5)	12 (22.2)	28 (51.9)
		3	4.56	0.74	0 (0)	1 (1.9)	5 (9.3)	11 (20.4)	37 (68.5)
		4	4.28	0.81	0 (0)	1 (1.9)	9 (16.7)	18 (33.3)	26 (48.1)
Soc Learn	26. The teacher is an active listener, guiding only when necessary as the students generate and explore ideas.	2	3.44	1.06	0 (0)	12 (22.2)	17 (31.5)	14 (25.9)	11 (20.4)
		3	3.91	0.92	0 (0)	5 (9.3)	10 (18.5)	24 (44.4)	15 (27.8)
		4	3.52	0.99	0 (0)	10 (18.5)	15 (27.8)	20 (37.0)	9 (16.7)
Soc Learn	27. The teacher has a framework in place to ensure that each member of the group is responsible for contributing to group products.	2	2.94	1.28	4 (7.4)	19 (35.2)	10 (18.5)	6 (11.1)	9 (16.7)
		3	3.91	1.03	1 (1.9)	5 (9.3)	10 (18.5)	20 (37.0)	18 (33.3)
		4	3.35	1.08	1 (1.9)	13 (24.1)	15 (27.8)	16 (29.6)	9 (16.7)

In the narrative below, practices are characterized as “quite prevalent” when the combined percentage of respondents selecting a Likert rating of five (“To a Great Extent”) or four was at least 67%. A combined rating at this level was used to support the claim that the particular teaching approach occurred with great regularity in the UWRF program (Research Question 2), the respondent placed a great value on the particular teaching approach (Research Question 3), or the teaching approach occurred with great regularity in the classroom of the respondent (Research Question 4).

Respondent Perception of the UWRF Summer Physics Training Program With Respect to the Five Principles

In this section, we will examine the teachers’ responses for Questions 1-27, with respect to Research Question 2, regarding the degree to which a particular approach occurred in the UWRF program.

Principle 1: The Constructivist Principle

Survey questions 1-10 addressed the Redish’s Constructivist Principle, which was defined in Chapter 2.

Results reported in Table 5 indicated that approximately 78% of the respondents felt that the UWRF program has students explore concepts by gathering data and searching for relationships, and nearly 67% felt that the UWRF program often provided some sort of engagement for the student when a new topic was introduced. As was discussed in chapter 2, these are important components of the Constructivist Principle. About 64% percent of the respondents also felt that they were encouraged to explain their

observations in their own words through a variety of methods, and they felt that many of the observations were specifically designed to address common physics misconceptions. In addition, nearly 60% indicated that the UWRF instructors often used student contributions to build bridges to unfamiliar material as well.

Only 24.1% of the respondents felt that the UWRF instructors regularly checked for student prior knowledge at the start of a new unit, and just over one third of the respondents felt the program utilized discrepant events to challenge students' preconceived notions about physical phenomena. One possible explanation for the lower rating in terms of assessing student knowledge could be gleaned from a free response quote on the survey in which a student wrote, "We were treated like we were all physics teachers, so prior knowledge was assumed." However, another student also indicated that, "I loved that [our instructor] could use our experiences to develop his lessons. He also was able to point out where students would have misconceptions and told us how to handle them." A theme that seemed to emerge from the data was that physics teachers in the program did not indicate this was an issue, but non-physics teachers seemed more aware of it.

Principle 2: The Context Principle

Survey Questions 11-13 addressed the Redish's Context Principle, which was discussed in Chapter 2.

Results from Table 5 indicate that nearly 89% of the respondents felt that the UWRF program used material that the students could relate to often. Exactly half of the respondents felt the instructors "restricted the frame" when introducing new material, and

added more real life elements later on in the unit, and 46.3% of the respondents felt the UWRF program took the time to model for students how to recognize what is relevant and what is a distraction in a particular situation.

Principle 3: The Change Principle

Survey Questions 2,8,9,and 14-17, addressed Redish's Change Principle as discussed in Chapter 2.

Just over 85% of the respondents indicated they felt the UWRF program used multiple representations to present material, and 63% felt the UWRF instructors took the time to teach them how to translate between the different representations as they were used. In addition, 64.8% felt the UWRF staff had the students demonstrate understanding of concepts using a variety of methods on a regular basis, and just over 59% indicated the UWRF program often used student contributions to build bridges to new material.

On the other end of the spectrum, 24.1% of the students felt the UWRF program assessed student prior knowledge often, and 46.3% felt that concepts were introduced multiple times with more "real life messiness" added on each new introduction.

Principle 4: The Individuality Principle

Survey Questions 18-22 addressed Redish's Individuality Principle as discussed in Chapter 2.

None of the teaching practices in the survey pertaining to the Individuality Principle received a high proportion of 4 and 5 ratings. The highest scoring practice was question 18, asking if the UWRF staff used varying teaching methods to address multiple

intelligences. Just over 43% of the respondents felt UWRF did this on a regular basis. About 4% felt the UWRF program regularly addressed students with special needs, while less than 2% of the respondents felt UWRF modified lessons to address students' cultural background differences on a regular basis, and none of the respondents indicated UWRF modified lessons for non-English speaking participants regularly. It should also be noted that nearly 22% of the respondents checked "don't know" for the question about cultural backgrounds, and nearly half of the respondents did this for the questions concerning non-English speakers and students with special needs. When specific case study participants were asked about this in interviews, they indicated that nobody in the program had special needs, and everyone spoke English as their primary language, so they never observed modifications being made by the River Falls staff. This was their reasoning for checking "Don't Know" for survey items concerning addressing non-English speaking students, and students with other special needs.

Principle 5: The Social Learning Principle

Survey Questions 19, and 23-27 addressed Redish's Social Learning Principle as discussed in Chapter 2.

Nearly 90% of the respondents indicated that teacher-student interactions were encouraged often, and that students felt comfortable interacting with the teachers in the UWRF program. In addition, 72.2% felt the program often encouraged a group approach to problem solving, and nearly 75% felt that exploration of material in class often occurred in a group- oriented format. Also, 27.8% felt the River Falls program often used a framework to ensure each member of a group project was responsible for

contributing to the product, and 46.3% felt the instructors in the UWRF program often acted as an active listener, guiding only when necessary as students generated new ideas.

Respondents' Perceptions of What They Value in the Teaching of a Lesson With Respect to the Five Principles

The 27 survey questions from Section II were revisited once again, but this time they were viewed within the context of Research Question 3. Here, participants indicated the value they placed on each teaching practice.

Principle 1: The Constructivist Principle

Survey questions 1-10 addressed Redish's Constructivist Principle as described in Chapter 2.

As can be seen in Table 5, respondents in the UWRF program place a relatively high value on all ten aspects of the Constructivist Principle addressed in the survey. Item three received the highest rating, with nearly 95% of respondents placing a high value on having students gather data and search for patterns or relationships. All but one item (item nine) had a combined percentage of over 67% of respondents selecting a Likert rating of five ("To a Great Extent"), or four. Item nine, which asked about the teacher using discrepant events to intentionally bring about disequilibrium in the minds of the students with respect to their preconceived mental models of a phenomenon coming into direct conflict with new observations, fell just short with 66.6% of the respondents rating this item as a four or a five.

Principle 2: The Context Principle

Survey questions 11-13 addressed Redish's Context Principle as described in Chapter 2.

The respondents placed a high value on the teaching practices in all questions related to the Context Principle as seen above in Table 5. Upon examining the table above, it can be seen that a full 100% value using relevant examples for their students whenever possible. Just over 72% of the respondents believed in restricting the frame when presenting material. In addition, just over 70% of the respondents indicated they valued taking time to model for students what is relevant and what is a distraction in a particular situation.

Principle 3: The Change Principle

Survey questions 2,8,9, and 14-17 addressed Redish's Change Principle as described in Chapter 2.

As seen in Table 5, respondents indicated they valued the practices described in nearly every survey item addressing the Change Principle as defined by Redish. Item fourteen received the highest rating with 100% of the respondents ranking this item as a four or five. In addition, 90.7% of the respondents also felt it was important to teach students how to translate between the different representations of a concept during the teaching process as well. Two items in the change section, each received combined percentages below 67% for Likert ratings of five ("To a Great Extent"), and four. These items pertained to using disequilibrium as a teaching method (item 9), and presenting concepts multiple times, each time adding more real life messiness to the situation (item

16), which received scores of four or higher by 66.6% and 61.1% of respondents, respectively.

Principle 4: The Individuality Principle

Survey questions 18-22 addressed Redish's Individuality Principle as described in Chapter 2.

Table 5 indicates that respondents valued some, but not all, teaching practices with respect to the individuality principle. Item 20, which addressed modifying instruction for students with diverse cultural backgrounds, received Likert ratings of four or five from just over 35% of respondents. The highest scoring question, item 18, received ratings of four or five from 83.4% of survey participants. Item 18 indicated using varied teaching methods to address different learning approaches or multiple intelligences. Closely tied to item 18 was item 19, which asked if teachers valued using varied assessment methods to address multiple intelligences. For this item, 74% indicated they valued this practice.

Principle 5: The Social Learning Principle

Survey questions 19, and 23-27 addressed Redish's Social Learning Principle as described in Chapter 2.

Table 5 indicates that respondents of the UWRF Summer Physics Training Program value all teaching practices described in survey items addressing aspects of the Social Learning Principle. Item 23 was rated as a four or five by 100% of the respondents. This item addressed the importance of an atmosphere where interaction

between students and teachers is encouraged, and where the students feel comfortable asking questions. Over 48 out of the 54 respondents, or 88.9% ranked this item as a five. Item 26 and 27 each received the lowest percentage of fours and fives for this section of the survey. Item 26 indicated the teacher should serve as an active listener guiding only when necessary as the students generate ideas. For this teaching practice, 72.2% of the respondents ranked this item with a four or five. Item 27 indicated the teacher should have a framework in place to ensure each member of a group is responsible for contributing to group products. Here, 70.0% of the respondents ranked this item as either a four or five.

Respondent Perception of What They Use in Their Classroom With Respect to the Five Principles

The 27 survey questions from Section II were visited one final time. This time they were viewed within the context of Research Question 4. Here, participants indicated the degree to which they used a particular teaching practice in their own classroom.

Principle 1: The Constructivist Principle

Survey questions 1-10 addressed Redish's Constructivist Principle as described in Chapter 2.

Survey item six regarding the degree to which observations and experiments are carried out to address common physics misconceptions had the highest overall percentage for this section of the survey, with nearly 91% of the respondents ranking this item as a four or a five. Just over 85% of the respondents indicated that starting a new unit with some form of engagement such as a demonstration, a thought provoking question, or a

classroom discussion occurred with great regularity in their classrooms. Using discrepant events to place students in a state of disequilibrium (item 9) earned the lowest overall score of 46.3% of the respondents indicating they use this practice often. Assessing student prior knowledge was ranked as a four or five by 51.9% of the respondents. Although roughly half of the teachers reported using pre-assessments regularly, given the attention in the research to the prevalence and change-resistance of student perceptions in physics, it is somewhat surprising that this figure is not even higher.

Principle 2: The Context Principle

Survey questions 11-13 addressed Redish's Context Principle as described in Chapter 2.

Items 11-13 were all rated with an average above 3.75, indicating that they are used relatively often by respondents. Item 11 had the highest percentage of respondents indicating they use this practice in their classroom, with just over 87% rating it a four or five. This item stated that the teacher uses examples that the students can relate to. In addition, 61.8% selected a four or five regarding restricting the frame when introducing new material, and 56.3% indicated they often model for their students what is relevant and what is a distraction in a particular situation.

Principle 3: The Change Principle

Survey questions 2,8,9, and 14-17 addressed Redish's Change Principle as described in Chapter 2.

Items 2,9, and 16 received relatively low scores compared to other items in this section of the survey. Item 9, which involved using discrepant events to put students in a state of disequilibrium received comparatively low ratings, with approximately 46% of the respondents assigning this item a four or five. Item 16 was close indicating that about 54% of the respondents introduced concepts multiple times and made them more complex to a relatively great extent in their classrooms. Item 14, which pertains to using multiple representations to teach material, received the highest ratings among this cluster of items relating to the change principle. Just over 92% of the respondents indicated they used this approach to a relatively great extent in their classrooms. It should also be noted that a closely related item, question 15, which asked respondents if they took the time to teach students how to translate between various representations presented, also ranked relatively high, with 85.1% of the respondents selecting ratings of four or five. As mentioned in Chapter 2, the ability to utilize multiple representations and to translate between them is an overarching skill that permeates all disciplines.

Principle 4: The Individuality Principle

Survey questions 18-22 addressed Redish's Individuality Principle as described in Chapter 2.

Only one of the survey items in this cluster, question 18, which addressed the use of varied teaching methods to address multiple intelligences in the classroom, was identified by the respondents as being used in their classrooms often or to a great extent. In all, 75.9% of the respondents ranked this item as a four or a five. Just over 61% of the respondents indicated using varied forms of assessment for multiple intelligences on a

regular basis, and the same percentage also indicated they regularly modify lessons to address students with special needs. Also, only 18.5% indicated they regularly modify lessons for the cultural differences present in their student populations, and 24.1% indicated they modified lessons on a regular basis for students whose primary language is not English.

Principle 5: The Social Learning Principle

Survey questions 19, and 23-27 addressed Redish's Social Learning Principle as described in Chapter 2.

Table 5 indicates that respondents of the UWRF Summer Physics Training Program value all teaching practices described in survey items addressing aspects of the Social Learning Principle. Item 23 was rated as a four or five by 100% of the respondents. This item addressed the importance of an atmosphere where interaction between students and teachers is encouraged, and where the students feel comfortable asking questions. Over 48 out of the 54 respondents, or 88.9% ranked this item as a five. Item 26 and 27 each received the lowest combined percentage of fours and fives for this section of the survey. Item 26 indicated the teacher should serve as an active listener guiding only when necessary as the students generate ideas. For this teaching practice, 72.2% of the respondents ranked this item with a four or five. Item 27 indicated the teacher should have a framework in place to ensure each member of a group is responsible for contributing to group products. Here, 70.0% of the respondents ranked this item as either a four or five.

Comparison of Survey Responses Corresponding
to Research Questions 2 through 4

Analysis of the survey data with respect to the extent to which a participant felt a teaching approach described in a particular survey item was present in the River Falls program (Research Question 2), the value placed on that particular approach by the participant (Research Question 3), and the degree to which the participant was able to use that approach in his or her own classroom (Research Question 4), and an interesting pattern emerged. For all but two of the 27 survey items addressing the Redish principles, the participants consistently ranked the frequency of occurrence of that strategy in the River Falls program lower than either the value they placed on the strategy, or the degree to which they used that approach in their own classrooms. Also, the participants ranked the value they placed on all but the same two survey items higher than their ability to use the associated strategies in the classroom, or the frequency of the strategies occurring in the River Falls program. In other words, frequency of occurrence always scored the lowest, followed by use in the classroom, and the value placed on a particular practice almost always scored the highest.

If we assume that the respondents of this survey are true professionals who are striving to improve their teaching, then it should come as no surprise that they would place a high value on these survey items, which reflect physics teaching best practices born out of research such as was explained in Chapter 2. Perhaps these professional educators were able to recognize possible positive outcomes attainable by embracing the items on the survey, and as such, placed a high value on them.

Things become a little more interesting when one tries to explain why the actual use of these teaching approaches consistently ranked higher than the occurrence of the item in the River Falls program. It could be reasoned that River Falls may have introduced a particular item to the participants, the participants saw the value in the practice, and the participants then carried the practice over into their own teaching. Since the River Falls courses are only one to three weeks long, and a typical high school calendar spans approximately forty weeks, it is probable that the participants have more time to work with a certain item than the instructors in the River Falls program had time to show them. When taking the length of the courses into account, a possible explanation for this trend in the data can be formulated. Of course it is also possible that the River Falls instructors simply did not utilize the practice contained in the survey item enough, and the participants took what they could from the program and expanded it to suit their own needs, or that they adopted the practice for reasons not influenced by the River Falls experience. Although teacher interviews conducted as part of the case studies for this research shed light on the degree to which the River Falls experience influenced participants' physics pedagogy, no baseline data was gathered to establish teachers' practice prior to joining the program.

The two items that did not follow this pattern were items 9 and 21. Item 9 involved the instructor using discrepant events to set up cognitive conflict for the student to get them thinking. For this item, value was still ranked highest on the Likert-Scale, but the frequency of occurrence at River Falls was slightly higher than the degree to which the participants indicated use in their own classrooms. One possible explanation for this

is that many teachers are uncomfortable with the idea of “purposely setting kids up to trick them.” This apprehension came up in the survey free responses. One teacher specifically stated that she did not like to trick or confuse her students intentionally for any reason. If other participants felt the same way, this could explain why this item ranked lower for actual use than for occurrence in the River Falls program.

Item 21 involved teachers modifying their instruction for students whose primary language is not English. For this item, value and use in own classroom rank equally, and both of them rank nearly three times higher than the occurrence of the practice in the River Falls program. A possible explanation for this is that the ethnographic makeup of a high school classroom may look significantly different than the ethnographic makeup of the students in the River Falls program. If English language learners are not part of the student body, then it stands to reason that River Falls would not practice this item with any regularity.

UWRF Summer Physics Training Program Student Case Studies

This section describes the experiences of seven students of the UWRF program through case narratives. Each participant was a practicing teacher, with years of experience ranging from as few as six years, to as many as 26 years in the classroom. The data in the narratives was gained from personal interviews and portfolio artifacts, and was used to answer the following research questions:

Research Question 2: What aspects of a program specifically designed to develop physics teachers' knowledge of physics content and pedagogical skills were present in the target program in this study?

Research Question 3: What aspects of a program specifically designed to develop physics teachers' content knowledge and pedagogical skills were viewed as important or useful by participants?

Research Question 4: What aspects of a program specifically designed to further physics teachers' practices were used in the classrooms of participants?

Additionally, the data was analyzed and synthesized across each case to provide more in-depth answers to the research questions.

Each case narrative provides a description of the case participant's reaction to his or her experience in the River Falls Summer Physics Training Program. Categories that emerged within and across cases included participant reasons for entering the program, initial level of preparedness to teach high school physics, comparing the undergraduate physics experience to the River Falls physics experience, and use of content and tactics from the River Falls program into the participant's classroom. With respect to use, several aspects were explored such as introducing a new unit, the use of multiple representations to convey data, teaching students how to translate from one form of data representation to another, teaching in the laboratory setting, and accommodating students with special needs. These categories were used to organize the data.

Each narrative describes the influence of the River Falls program on the participants from the dimensions of professional learning using the themes that emerged

from the data. Quotes from the survey and interviews were used to support the findings. All names of the participants were changed for confidentiality. In addition, specific information about the location of the district in which the participant currently teaches was made intentionally vague. The experiences that led to professional learning were also highlighted to illustrate the effective components of the River Falls program and the benefits to participants.

Through the analysis of the River Falls case studies, it was evident that each teacher valued some aspects of the program, although the degree to which each aspect was valued differed from case to case. It was also revealed that the subject matter taught by the participants seemed to have an effect on the value placed on various program aspects. That is, teachers who were currently teaching physics at the time of the study seemed to have different values than teachers who had never taught physics. Clear differences were also present when participants described their undergraduate physics experience to their experience in the River Falls program. This was true even when the participants attended the same university with the same professors for both their undergraduate and graduate physics training.

Direct quotations from the interviews and the surveys have been included to illustrate the case studies. The quotations and excerpts are presented as originally spoken or written. No attempt to correct grammar, spelling, or phrasing was made. The only corrections made were those that were needed to clarify the statements spoken or written. Names of specific universities were also deleted for confidentiality. Word substitutions for confidentiality or clarity are enclosed in parentheses.

William

Background William is an experienced teacher from a rural, impoverished school district in Wisconsin. He is in his 23rd year as a teacher in a high school with approximately 150 students, grades 9-12. William's teaching situation shows evidence of life in a small, rural school district. He believes that somewhere between 65%-75% of the students in his district are eligible for free and reduced lunch. He currently teaches Advanced Placement Statistics, algebra II, chemistry, trigonometry, physics, and principles of technology. In addition, he also drives a school bus, and coaches track. He has also served as the athletic director and cross-country coach. During his 23 years in the classroom, he has also taught geometry, algebra I, applied math, and vocational math.

Reason for Entering the River Falls Program Like so many other physics teachers, William was originally trained in a different field. His specialty was chemistry, and he began his teaching career with a major in chemistry and a minor in mathematics. In an interview conducted in the summer of 2010, William commented on how he became a physics teacher:

And when I was hired [in 1988], I was hired to teach physics, chemistry, and math basically. I did not have a physics license, and so when I was hired, my principal at the time said, "Can you teach physics?" And I said I had ten credits as an undergrad. He said, "Great, fine, you'll be good." And he got me an emergency license through the DPI [Wisconsin Department of Public Instruction].

As was mentioned in Chapter 2 of this paper, many districts throughout the country have hired their physics teachers in a similar manner. Ten credits of undergraduate physics (or

sometimes even less than that) are often what new physics teachers bring into the classroom at the start of their careers.

William knew that he needed to take a minimum number of credits to maintain his emergency license in physics, and it was at that time that he heard about the program at River Falls. He began taking UW-River Falls physics education courses at the same time he began his teaching career. Like many others in the program, once he started taking classes, he soon discovered that this program could serve as a vehicle for him to obtain physics certification. Soon after, he was persuaded by instructors in the program to continue his training even further, and he eventually earned a Master of Science Teaching—Physics degree in 1996.

Preparedness When asked about how prepared he felt to teach high school physics, William explained that he underwent a rather intense transformation:

I don't think I was any less confident in my ability to teach physics than anything else. I was strong in math... I felt I was okay, but boy, I wasn't prepared (laughter), and it wasn't until I got into the River Falls program I realized that there was a whole world there that I just had not understood or didn't—and doing it calc-based as an undergrad... That was really, really, tough. And I don't know why I ended up in that track in college-- it certainly didn't serve any purpose in terms of teaching high school kids.

William had two courses of calculus-based physics, similar to most any university engineering program, as his preparation for teaching physics at the high school level.

Comparing the Undergraduate Experience to the Graduate (River Falls) Experience When comparing his undergraduate physics experience to his River Falls experience, William noted some key differences:

As an undergraduate, I think it was just a matter of giving us the five credit calc-based physics we needed to meet the requirements for the degree. When I got to River Falls, those people had a completely different philosophy. Even like the coffee room, where it was—you could go sit and work problems—I can remember Curt saying that, you know the philosophy of that was so that professors and students could sit together and work on problems in a non-intimidating environment. There was never an “us versus them,” never a professor versus kid... I felt like we were as a group collectively coming up with solutions to problems, and that [the instructor] was as excited to solve it as we were sometimes, and—it was like an art form that—I don’t even know how to —it was something that I never learned as an undergrad, I know that.

When asked about the lab experience William had as an undergrad, his answer was short and to the point as this excerpt from the interview clearly shows:

I: “Did you do labs in your undergraduate physics at [your undergraduate university]?”

William: “I think so. Yes, I know we did. They had no impact on me.”

I: “Were they similar to what you did at River Falls, or did one program stress something different than the other?”

William: You know the thing I think that the River Falls program taught me was that you could do physics with everyday stuff. The strings and sticky tape stuff, you know...I think that River Falls made it okay to do physics without fancy equipment and all of that stuff. I think it was just a whole different philosophy. I just don’t remember very many experiments as an undergrad. I remember a lot that I did at River Falls, but I don’t think I remember a whole lot of what I did as an undergrad.

So it was clear that the physics courses William had completed just prior to teaching did not, in his estimation, prepare him for what he would need as a high school physics teacher. Throughout the interview, he commented on the student-centered atmosphere created by the instructors in the program as essential for his success. He commented specifically on the program atmosphere in the excerpt below:

You know, we'd be in a lecture environment and a discussion format. I think the pressure was off. I mean they weren't going to weed us out of the program-- we weren't going to flunk out of college. We were adults [and] we were there to learn. I think that was the first thing that was the most important. They were there truly to help us and develop the knowledge base that we had, and then the art of teaching physics. And then they took that information, they were never condescending, they knew we all came from very diverse backgrounds... They never made us feel dumb, they just were there to help. And everything about the program was to develop us as teachers—as people so we could go back to our classrooms and help kids that would be in our rooms.

During this same answer, he also wonders aloud about the possible impact of the program when he says, “And you know-- How many kids has that program affected [very emphatic]? Yeah, I got affected as an individual, but how many other kids were impacted by that program?” He was referring to the middle and high school students who have been taught by teachers who were trained in the River Falls program.

William was then asked to comment specifically on things he valued about the training he received in the River Falls program. He began by commenting on the financial aspect of the program, but as you will see, William soon valued much more than the low cost of this training program:

...One of the summers I remember going down to the Fermi Lab in Chicago on a school bus, and we stayed in hotels, and they paid for food, and my beginning, I was getting three credits, I was getting a stipend, I was getting room and board, I was getting notebooks, I was getting—I mean, it was a made deal... I used to think, “I’m ripping off NSF because I’m getting free room and board, and that’s just crazy.” And when I got done, I’m like, “Wait a minute, NSF made—the best investment in their resources was putting us in those dorms, because it forced us to just eat, sleep, and breathe physics for three straight weeks.” It was excellent—I mean, amazing.

When asked to elaborate about what life was like living in a dorm 24/7, with a bunch of other teachers training to be physics teachers, William shed some light on that experience:

And I think in my mind, one of the most valuable parts of the program was putting us all in those dorms, because we ate, and slept, and showered, and peed and pooped physics (laughter). And I can remember going downtown to the bars after we had studied, and we'd literally fill cocktail napkins with physics problems for hours. And we were downtown, we were drinking beer, we were laughing, we were getting silly, but we were working on physics 24/7. And forcing us to live in the dorm room with another one of the people, meant even when you got up in the morning, you talked physics. When you walked to go eat, you talked physics. When you were eating breakfast, you talked physics. There was so much knowledge gained outside of the classroom and that was so powerful.

And when asked about specific things that he gained outside of the classroom, William mentioned some valuable things he gained from the program that one might not readily associate with a physics teacher training program:

...But in terms of, like, content and information, it was obvious that I learned a tremendous amount about physics. I really didn't have a good physics background at [my undergraduate university]. I had ten credits of calc-based physics, but not really what I needed to teach high school kids. But I think more importantly—I mean, I lived in the dorms, I learned to understand physics better, I developed friendships, and a network of people through that experience at River Falls, and I don't think the growth for me can be defined just in terms of content. I think for me personally, and for my students in science, I grew as a person through that whole experience. And to say that I learned this experiment or I learned that experiment, or I learned whatever—I learned so much about me, and how to teach, and how to interrelate with kids, and make them excited about learning physics, and I can't even imagine my life today, and doing what I'm doing, and raising my family, and teaching, and all that—without that program. It was so powerful and such a huge part of my growth and development as a teacher...

William was also impressed by the philosophy of the program to tackle misconceptions held by the participants with regards to the content head-on. He remembered selecting his thesis topic with the lead professor of the program:

And I think River Falls taught me to think, and it taught me to enjoy thinking—to enjoy problem solving and overcome obstacles... River Falls was just—it's okay to face your weaknesses. I mean when [my major professor] encouraged me to do my Master's paper on a topic that was just the most difficult for me—resistance was something I just didn't get. And so he said, "Let's do a Master's paper on that." I said, "Dr. L--, that's my weakest area." He said, "Exactly, and we'll make it one of your strongest." And that was huge, you know? So it wasn't "run away from your fears", it wasn't "avoid what's difficult", it was "okay, let's take this on head on, and we'll overcome this, and we'll get through it."

Use in the Classroom The interview then focused on specific things that William was able to use from the program in his own classroom. One of the first things he mentioned in addition to his content being improved, was the group approach to solving problems, which fits in with Redish's Principle number Five; The Social Learning Principle:

The first and easiest thing to say is that my knowledge base increased exponentially. I mean my knowledge of physics was significantly greater. But remember again I came in as a ten-credit undergrad.

I think in terms of my students, and see I think about the impact of the program not just on my physics teaching, because I teach so many other things. I think the biggest impact for my students was the concept that we are going to work on this together—that it's not going to be me disseminating information and you digesting it—it's going to be we are going to work on this collectively. I learned—and that, I think that was the biggest lesson for me at River Falls was that there were lots and lots of people involved in my learning. It wasn't just a professor, a notebook, a test. It was the whole gamut. It was a professor, the professional teachers,

the resource people, the other people in my classes, the network of group—you know the groups of people you slept with and hung out with, and lived in the dorms with. I think that community of learners aspect of my teaching and what my students get from my classes is probably the biggest thing that I can think of that I draw from the River Falls program. And it's—and obviously there's content. That's without a doubt something that my kids wouldn't have ever gotten had I not been a part of that program.

Introducing a New Unit William was then asked how a typical lesson runs in his class. He mentioned strategies consistent with Redish's Five Principles:

If we're going to talk about friction, or if we're going to talk about electronics—we're going to talk about something, I mean, we'll go so far as to go out in the parking lot, and look at the car, and I'll draw on their experiences driving, or we'll go outside and pour water on the ice and see that the coefficient of friction is different, and I relate it to μ , and why do we put wood in the back of a pickup truck? I do a lot of trying to draw something that they've already experienced, or seen, or have witnessed, or can go out and see and try, and touch and feel... I really, really, really try to start with something that can anchor what we're learning and what we're going to talk about in something they've already done or experienced, and then get into the theory of it.

The Use of Multiple Representations He then goes on to talk about how he presents the material in a variety of ways:

I am very much a graphics, figures, pictures, diagrams—I don't do enough writing paragraphs and stuff, I know that we should—it's not something I'm good at. I do more of that in my chemistry classes, I guess. And actually, I do a fair amount in my stats class, but physics to me is hands on, graphs, tables, figures, pictures, arrows—I mean, a physics problem to me should be—and anything you do in physics—should be pictures—you know—this is what I know, this is what I'm trying to find, and here are

my equations that I think I'm going to use, and here are the variables—you know—identify the variables that I know, and—you know, it's very systematic.

Translating from One Representation to Another In response to his answer regarding multiple representations, William was then asked if he felt that students are naturally able to translate from one form of data representation to another, or if this is something that needs to be taught. He replied: “I have to guide that. It's very obvious that they can't do that... It takes a long time.”

He then gave several examples of how he had to guide students from the data, to the shape of the graph, to the equation, to an explanation, and he added:

You know—and that to me is the most fun. I mean, you get into that discussion with kids, and who cares how much physics you get done? If they can learn to think, they've got two thirds of the problem solved before they've even started working it out.

He also added some humorous conversations he has had with his students that most any physics teacher can relate to:

They just can't—and I think they're—they just want to be done. They're like, okay, $t = -5$. Okay, what does -5 seconds mean to you? “I don't know -- it's what the equation said. Here, I'll show you my work.” No, that doesn't make any sense to me—it doesn't make any sense to you. What does that mean (laughter). Well, let's look at where that number came from. How did you get that number? “Uh, I put it into this equation. I used this one.” Well, what does that equation tell you? “I don't know.” Well—that process—that takes a third—probably two thirds of teaching physics is “What does that mean?” What does that mean in the context of this problem? How can you interpret what that solution means?

William also described the frustration that physics teachers go through just trying to get their students to read the problem carefully, and formulate a plan before jumping in and crunching numbers.

You know—how many times do you have to deal with kids that don't realize that when the problem says that the car starts from rest that initial velocity is zero? It takes me a week or two to make them realize that. So—"There's really no information here." I'm like, "Yeah there is, read the problem. Read what it says. What does that mean? Starting from rest—what does that tell you?" "Well, I don't know (laughter)." Well, is it the distance that they're traveling?" "No." And it's like—that to me is—you talk about—one of your questions earlier was you know, do you get through a lot of information? I literally could spend twenty minutes really making them think and understand what is in the problem. How many times do you read this problem before you embark on a solution? How many—is it okay to think this is the equation I'm going to use instead of just putting numbers in and saying, "Wait a minute, there's two unknowns in this equation. Something is wrong here." Okay, then is it okay? "Well no, it's the wrong equation, I screwed up." No, you didn't screw up, you've just eliminated that as a possible solution. So let's back up rethink the problem, we're not going in that direction again, because we know that didn't work, so let's not erase it, let's leave it, then, we'll move on in a different direction. But, oh my God! It takes a long time.

As any physics teacher can tell you, many hours of instructional time in physics classrooms across the country are spent having these exact same conversations. Events such as these clearly show that a strong grasp of physics content, as well as a clear understanding of what skills high school students need to develop in order to solve physics problems are mutually essential.

The Laboratory Setting William mentions that because of the budget situation in his district, he is not able to conduct many lab experiments with his students, but he did shed some light on how the experiments he is able to conduct are laid out:

We'll discuss whatever it is that lab is going to be about. I'll have the equipment set up—I actually a lot of times have them help me. I find that they get so intrigued by the stuff that I'd rather have them play for a little while with it, and then figure out what's going on. You know, if we're going to run with the air track, I'll set the air track up and I just say, "Why don't you just go play with it for a day and figure out what you're doing?" And then they just play with it, and they're like, "Hey we could do this, or

we could do this, or this.” And I’m like, “Here, try this.” And they’re like—then the experiment kind of starts and we talk about collecting data, and we talk about how we can manage collecting this data... So, if I’m going to run an experiment, I—what a lot of times I’ll do is kind of have the stuff sitting out, and then we’ll kind of go back as a group, and we’ll start kind of putting things together and then we’ll start saying, “Well, we’re going to have to collect this.” Then we work at whose going to collect the data and how is this going to be run?

This method of having the students explore and then discuss how to collect data is in line with Redish Principle #1, The Constructivist Principle, and Principle #5, the Social Learning Principle. He also stressed that getting the “right answer” in the lab was not as important to him as the students having the lab experience:

Well, if it’s kind of a closed experiment—like if we’re shooting for a value—like if we’re calculating “g” or something like that and if they get 8.9, or 10.1, or 10.3 or—I don’t really care about the numbers that they’re getting necessarily. When they walk away and they just kind of get it, I feel like we’ve met our goal. I don’t want the kids to feel that they have to do it within two tenths, or one tenth—it’s not analytic chemistry where you’re getting graded by the mass of product. And some experiments just flat out don’t work for whatever reason, we just can’t get it to work—you know we try something new, and it fails miserably, and—is that a bad experiment? I don’t think so. I think it’s as valuable as anything else you can do. I mean you just kind of chalk it up and say, “Whoa, that just didn’t work at all.” We talk about what happened and why don’t we think it worked, and what do we think we should have done better, and then we just kind of move on. It’s part of life. Not everything I’ve done in life worked.

Accommodations William indicated that he occasionally has students in his class that truly are not ready for high school physics. He explains how he deals with those students:

Physics is really not as cut and dry in terms of grading as my other courses, just because of the nature of the beast. You know, when I’ve got a kid that’s just not up to speed, he or she is going to pass—we’ll sit down and talk about what they’ve been able to accomplish. I would say I really

steer away from whatever the red pen stuff is, because that's just not going to work in that context. And I—you know, I would much rather have a kid come in and take my course knowing they're probably not going to fail and at least be exposed to the physics as opposed to steering clear because they're afraid of getting chewed up and spit out... [I tell the student] "I'm really sorry, I know you're not going to get this, but we're going to try to get you through as much as we can. We're going to try to get you to pass the class. We're going to get you to understand as much as you possibly can. But we all know you're just not going to be able to do everything that's required. And I'm really hard pressed to fail a kid. In that situation, I just can't fail a kid because that was the only class available, so I screwed him to the ground and buried him? That's just not—that doesn't serve anyone's purpose.

So William is willing to bend the expectations to ensure that each student has a chance to succeed.

The Portfolio For his portfolio submission, William chose a lesson on dimensional analysis, a topic usually discussed at the beginning of a physics or chemistry course. William felt that the constructivist and context principles factored most heavily in his decision to use these lessons. He explained that he was using “real-life situations” such as planning a vacation to make connections to working with conversions between metric and English units. He pointed out that the River Falls program did not spend as much time on dimensional analysis as he does, but it has been through direct experience with his students that he has discovered that this is an area where many of them need extra assistance to be successful. Consistent with his interview responses, William was quick to point out just how difficult certain scientific processes such as dimensional analysis are to students, and how careful we as teachers have to be so as not to leave these students behind. Consistent with the research discussed in Chapter 2, William believed that making the scientific exercise tie into the everyday lives of the students as

much as possible would increase the chances that the student would internalize the concept and begin forming an accurate mental model from which to build upon.

Closing In closing, William had some words for the physics education community in general, and the River Falls program specifically:

I think there needs to be a sensibility that physics is frickin' scary to a lot of people, and it's okay to be intimidated by it. That's natural—it's not okay, you shouldn't feel that way, but it's okay, and you can overcome that. So, the River Falls program took me in and said, "Okay William, you're a chemist and you've got the math background, you're not a physicist, but that's okay, we can get you there."... I think that the next generation needs to know it's okay to be confused, and it's okay to be frustrated, and it's okay to not know what you are doing... I don't think you're going to get a lot of physics teachers per se who are going to come into the profession as physics majors. They're going to get a lot more people like me who start out in one area and then end up in physics. I mean, why would you become a physics teacher and barely make \$50,000 a year when you could become a physicist and make \$150,000, you know—I mean it's laughter)...

He then elaborated on another point brought up by many teachers in fields other than physics:

...Are we going to convince young people to become physics teachers when there's just not a lot of—and it's not even the money that bothers me—it's the respect. I just wish people respected what we do...Teaching is important. This is an important thing, and [people] should value what they [teachers] do." And I don't think we have a lot of that right now. I think that's probably one of the most frustrating things is that I just don't think people respect or value necessarily what we do.

Like so many others who are currently teaching high school physics, William came into the field with a different background. Early on, he discovered the unique challenges faced by high school physics teachers and searched for a program where he could receive teacher-specific training for physics. Upon completing the training, he was able to carry

aspects of what he learned and valued into his classroom, where he spends every day with a large population of underrepresented students. William noted the student-centered atmosphere he felt was present at River Falls as important for his success in the program. He mentioned that the program allowed him to grow as a whole person, and did not simply focus on his skills in the classroom. William noted that the instructors in the program encouraged him to pursue ever-higher goals in his education, and insisted he complete his final project on a topic that he described as one of his weakest. He indicated that there was so much more than a professor, a textbook, and a classroom. He mentioned the sharing sessions, the professional networks he was able to build, the resource people available if needed, and of course, the course content. William also pointed out that most physics teachers at first find their way into physics classrooms with backgrounds in other disciplines. The research discussed in Chapter 2 agrees. As such, he indicated the importance of creating training programs that will adequately prepare these teachers as they make the transition into the physics classroom.

Gary

Background Gary is an experienced teacher from a medium sized city in Wisconsin. He is in his 25th year as a teacher in a high school with a population of approximately 1500 students, grades 9-12. Gary currently teaches AP-Physics-B, physics, and physical science, but has also taught 7th grade Life Science and 10th grade Biology. In fact, he taught for fifteen years before he taught his first physics course.

Reason for Entering the River Falls Program Initially, Gary looked into the River Falls program as a way to maintain his Broadfield Science certification. After completing a few courses in the program, he realized he was close to becoming physics certified, so he decided to complete the program. His decision to continue was also motivated by the fact that he knew the physics teacher in his district was nearing retirement, and his administration had spoken to him about the difficulties involved in finding a physics teacher. As we will soon see, other motivating factors emerged as he continued with the program.

Preparedness He noted that as he began teaching his first physics course, he felt confident that he would be able to teach the subject matter effectively. He mentioned that he had one year of undergraduate, algebra-based physics at a major mid-western university, fifteen years of actual teaching experience, and he completed four years of the UW-River Falls program before he actually taught his first physics course. Based on the research, Gary was well ahead of the typical teacher tackling physics for the first time.

Comparing the Undergraduate Experience to the Graduate (River Falls) Experience When comparing his undergraduate physics experience to his River Falls physics experience, Gary, like William, noted some key differences. In an interview conducted in the summer of 2010, Gary had this to say about his undergraduate physics experience:

There was a significant difference. My undergraduate courses were in a lecture hall with hundreds of students—and then of course there were the lab sections—I would say it was more of the traditional lecture and lab sequence. And during the labs, you read the book, you got the data, and you came up with, you know, the cookbook solution and explanation to

what was going on. You were really kind of proving what was already known.

And when asked about his experience in the UW-River Falls program, he commented:

Now, when I got to UW-River Falls, I guess I was almost expecting something similar to that, but because of the smaller numbers, and the focus of [not only] trying to get teachers certified, but also to help them understand the—truly understand the physics, I was able—with that kind of instruction-- I was able to spend time to understand what was going on. And also they exposed the different ways of presenting the information based on—whether it was other techniques or other teachers experiences. ... That's something that was not available to a typical undergraduate course, and the focus of River Falls was to get teachers certified as opposed to [my undergraduate experience where the purpose was] exposing physics... the way they [UW-River Falls] presented the material and the activities, and the way they interacted with us as students really helped me understand things much better.

When asked specifically how UW-River Falls “presented the material” in a way that helped him understand, he referred to the Modeling technique discussed at great length in chapter two. Here, Gary explained how it impacted both his learning in the program and in the way he teaches his own students:

The students were presented with a demonstration, and there was some general discussion. Sometimes there would be a discrepant event involved, or information you might summarize from the demonstration that didn't seem to fit the model you had in your head, so then we as students would then perform the lab, gather data, and then through integrated technology... the use of graphing that data, getting immediate feedback, and then coming up with a mathematical model impressed me—instead of being told about a law such as Newton's Second Law which everyone can recite mathematically if they know any basic science, and—you came up with it, and the experience of manipulating the data—it was almost like a sense of empowerment that you could go out and maybe try to find other relationships on your own... And that's what I pass on to my students, and I think if nothing else, that process of gathering the data and trying to see the data in new light—forcing you to do it without saying “Oh, by the way, this is the Law, let's make sure you get it for you lab”—I think that was the true science.

When asked about what components made the River Falls program successful, Gary commented on several. He mentioned the professional contacts he was able to make with other teachers in the program, and talked specifically about an event that occurs at the end of many of the classes taught in the River Falls program, the sharing session:

Every class there that I've taken in physics they have a physics sharing session toward the end of the—you know the end of the session—and it was a chance to see the demonstrations enacted, it was a chance to ask questions about it, discuss applications... you had support from the teaching staff—the faculty there at River Falls to help put it together, and [the set of demonstrations] are on a DVD or CD-ROM and you could take that with you... Yeah, no matter how good your notes are, there's nothing like seeing the original worksheet that was handed out and having a sort of collection— That's something specifically of teacher training-- it's huge as opposed to taking a basic curriculum and instruction course on science methods—you know—thinking back to when I was twenty-something and we had to perform some sort of presentation, for our fellow classmates, back at [my undergraduate university] sometimes you just kind of winged through it because you were assigned the demonstration and—that's what happened to me, I got assigned a demonstration and it's like “okay, I'll try to make this work for the class”, and you sit there and listen to everybody else's and you know, I don't remember a single thing about that, but when you're in a physics sharing session, and you have a chance to sit down and discuss experiences behind it —man! If you're going to become a physics teacher, that was the way to go—as far as getting that kind of information.

As mentioned earlier, the Modeling technique also made a strong impression on him, and he mentioned this many times over the course of the interview, and in his survey responses. In fact, he came up with an interesting analogy comparing Modeling and exercise with respect to training teachers about the importance of teaching our students to translate from one form of data representation to another:

It's funny you mention translation, because it seemed like at [my undergraduate university], we were taught at a very low level like memory translation—kind of—Bloom's taxonomy level-- Whereas at UW River

Falls, you had a much higher level of interpretive analysis and application. It seemed like at [my undergraduate university], memorize this and use it to solve the problem was this huge leap. Whereas at River Falls in the Modeling technique, you worked your way through all these levels of comprehension, and it's kind of like an athlete, instead of just running and trying to get faster, you were lifting weights, stretching, and doing yoga, and then running, and running in different ways, and you—yeah—you've got a lot more tools to work with to get the job done—to solve the problem.

Translation was focused on because Redish and several other physics education researchers have indicated this as an area where undergraduate physics programs fall woefully short in their preparation of high school physics teachers, and they deem it an essential skill that should be taught in any physics teacher training program. In fact, when Gary was asked specifically if his undergraduate physics program focused at all on teaching students how to translate, he said the following:

No. Plain and simple no. It was just a matter of “Can you take this equation and come up with the right answer?” And sometimes when you got to the complex problems like the two moving particles or bodies, when will they intersect? Up until I went to River Falls, I wasn't sure how to solve for those things, but as soon as I saw River Falls—how Modeling and the professors at River Falls did some things—especially graphically—then it seemed simple.

There were many aspects of the River Falls program that Gary valued as a participant. Specifically, he mentioned the small class sizes, the friendly interactive nature of the instructors, the family-like atmosphere that seemed to exist among the participants, fueled in part by the fact that they live together for at least three weeks each summer for several years in a dorm, spend eight or more hours per day in class, and often spend several hours each night studying physics. That causes fellow participants to form some very tight bonds. He elaborated further:

Oh, [it was] definitely collaborative. Again, it had to do with the sharing. When there was the physics sharing, the PTRAs, the professors, or just sitting there next to your fellow peers—you know—we already had our jobs, you know—we were sharing the battle stories, successes—whatever... [and] when you get stuck in a dorm for three weeks and there's a core of us, and you do that for three years in a row (Laughter) you're going to be family.

Use in the Classroom In terms of usefulness, Gary said the program “Gave him some background where he felt qualified to comment on physics... and adding physics courses... in the district he worked in.” Predictably, he also mentioned aspects of Modeling that form the context of his physics instruction. Here, he described a typical lesson in his classroom:

No, we will—when I do a demonstration, then we'll sit back and say “What are the possible variables?” And we just brainstorm at first, just to get stuff up there and generate discussion. And then we'll start narrowing it down as to what really is a variable and we have what is part of the control, and what is something we can possibly test in a cause and effect relationship. And sometimes we might have two or three different causes, and—yeah—all right, you compare this one as a cause, go ahead and work on it, you propose that—this group over here proposes that as a cause, you work on that. So, we're not all doing the same experiment at once sometimes.

He went on to describe the process further:

Then, they are released into the lab, and that's where I just sort of start monitoring and making sure the setups are basically right, asking them about their data. I'm basically repeating what I've seen done for me when I was a student. The setups are set up in such a way that they're getting data that at least makes sense as far as being able to make it into a graph, and that there's no boogey-men hiding inside the equipment (laughter) or something like that. So, once they collect their data and they have it graphed, then, they are to come up with some sort of mathematical relationship, and then they will grab the white boards—which is something that I haven't really talked about... But anyhow, once we get to that point, then as we start closing discussion, then I will be nudging the students towards an overall summary—seeing if they see—whether it's

Newton's Second Law, or a conservation of momentum equation or whatever—eventually we will get to what many professors or teachers will start with—a traditional lecture in where “Oh here is what Newton came up with,” and this is how it applies—see eventually we start working towards that.

It should also be noted here that the Modeling technique that Gary uses specifically addresses misconceptions, relies heavily on teaching translation, and is taught nearly 100% of the time in a laboratory format. According to Gary, lecture is done sparingly at the end of a unit.

Gary mentioned that his time at River Falls has allowed him to have a much firmer grasp of the physics content he presents to his students, which makes teaching his class in a lab-based format much easier than it would have been without his Modeling training.

The Portfolio Consistent with both his survey and interview responses, Gary utilized a Modeling lesson for his portfolio entry. As he described what his students did in the activity to investigate the relationship of position versus time and velocity versus time for a moving object, it followed precisely the Modeling method discussed in detail in Chapter 2. Gary's goal was to have his students derive both conceptual and mathematical relationships for position and velocity versus time, and he did this by having the students conduct an experiment, gather data, analyze the data, and finally discuss and present the data. Upon reflecting on the lesson he chose, Gary felt that the constructivist principle figured most prominent its design. He felt that the constructivist principle was the foundation for the other four Redish principles. He also mentioned that the individuality principle was important, because ultimately students must be

responsible for forming their own mental models of what it is they are observing. The student work samples that Gary submitted showed a work in progress. The students demonstrated varying levels of understanding, which Gary said was not uncommon early in the school year when this exercise took place.

Closing At the conclusion of the interview, he had a few more things to say about what he valued as a participant, and what benefits he feels his current students are reaping because of his participation in the program.

It was definitely the most rewarding college experience I ever had—to be trained that way—because it stuck. It opened up new doors to me. And by no means was all of it perfect, but I didn't expect perfection. But it changed the way I taught. It changed the way I viewed students. It changed the way I learned. I think their method of training teachers—especially—well, I don't care now if you've been certified as a teacher, or you're getting certified, I think they have probably the best program I've heard of—because there's not a lot of alternatives out there. And it had a huge impact on how I conduct myself as a professional... I guess, you know—this is as a science teacher in general—If you want students to truly understand it, they have to live it. And that's what that program taught me. Not—I had to dive into it—not just look at the book and memorize it. And my understanding and my appreciation for what could be understood was magnified. I would hope every kid at some point in their life goes through a science course that's like this—this is what it's all about—getting them to understand it in different ways—you know because the typical cookbook, textbook, fill in the blank kind of stuff that's—you know—that's not truly understanding it.

He also issued a word of advice for anyone looking for ways to create the next generation of highly qualified physics teachers:

Well, I know when I first started, that was very enticing when I realized that I could have most of my Master's paid for. To me, economically, that was a no-brainer. That got me excited—at least financially—about it. Right now, if I was a teacher—an undergrad, and I just got my basic Broad Field Science, and I'm thinking about going to River Falls for physics, and if I were to see the final bill to get the whole program and the

whole Masters, I'd be discouraged. Because to me, if greater—if there's a need for physics and chemistry teachers out there, then fund it (emphatic)- It's as simple as that. The National Science Foundation did them in the early '60's and this whole big crop of teachers showed up. And now they're saying we have to educate more engineers. Well then, fund the education of the teachers. Yeah—it's so simple.

Initially, it was the maintaining of a Broad Field Science certification, and nationally funded credits that led Gary to River Falls. Soon after, he discovered a new way of looking at physics, at the way he taught, and at the way he interacted with his kids. This fundamental change in his perspective occurred after he had spent fifteen years in the classroom as a teacher. The Modeling techniques, support network, and content knowledge he acquired along his road toward becoming physics certified and earning his Master of Science Education – Physics degree have, in his estimation, proven to be valuable assets to his teaching. Gary, like William, felt that the support network, and the sharing sessions greatly assisted him in his studies while participating in the River Falls program. Gary also mentioned the deeper level of understanding he was able to attain in the program, and his new found appreciation for what could be learned as a result of the teaching techniques he was exposed to. The student-centered approach mentioned by William that allows students to uncover scientific truths for themselves instead of simply being told what the answers are proved to be a powerful experience for Gary. Gary, William, and a growing number of physics education researchers appear to share the belief that programs designed to train physics educators should look different than programs designed to train other majors.

Kristi

Background Kristi is an experienced teacher from a larger suburban school district in Wisconsin. She has taught AP-Physics, Physics, Physical Science, and Mathematics for the past eighteen years. Her high school, grades 9-12, houses approximately 1100 students.

Though she began teaching physics her first year in the classroom, that was not in her plan as she graduated from college. She states that she “wanted to be a math teacher, not necessarily a science teacher, but that was the position that was available.” She also adds that though she felt proficient in the math, she “did not feel that [she] had a very strong lab background.”

Reason for Entering the River Falls Program Kristi realized she was going to need some additional training for her role as a physics teacher. She discovered a network of physics teachers in her area of the state, and began attending their meetings and sharing sessions. It was through this network of teachers that Kristi first learned about the Physics Teacher Training Program at River Falls. She started slowly, taking a class here or there, and mentions that she taught physics for four or five years before she fully committed to the program. Upon gaining entrance into the program, Kristi completed the requirements to earn her physics certification, and continued on to complete the entire Master’s Degree program offered at River Falls.

Preparedness She described her initial experience in the classroom as difficult, and goes on to say “I didn’t feel like I had a strong enough lab background, and so I was

basically teaching the kids another math class that they found extremely boring and not helpful to them.” Kristi, like many teachers teaching “out of field,” relied heavily on her math background, and as a result, she says, “I was just barely ahead of the kids... and truly, I was teaching it [physics] like a math class.”

Comparing the Undergraduate Experience

to the Graduate (River Falls) Experience

When Kristi was asked about her undergraduate experience in physics, she explained the impact it had on her as a high school physics program:

What I had as an undergrad was definitely—the emphasis was definitely on people that were going into research—were going into graduate programs in physics—were going into engineering. It was not at all (laughter) related to education or application to education. It was all geared toward research and engineering.

And when asked how her experiences in the program at River Falls differed, she explained:

Well, I think at River Falls, what they did for the teacher program that we were involved in—I mean, it was much more applicable—they made more connections to what you would do in the classroom—how would you apply it—you know, just the little teaching tips that they would give in the RA sessions or the—you know—even the lab work, you kind of approached it from a different perspective—at least I did after being in the classroom, and seeing what my students had to learn, or what I wanted my students to learn—so I would approach it differently. And I just think there was more applications available to the teachers rather than in my undergraduate program.

She also made it clear that she did not feel that the rigor in the River Falls program differed in any way from her undergraduate experience, she just explained that the focus was more geared toward what teachers would find useful in their classrooms. She explained:

I think [the lead instructors]—definitely their emphasis was on taking it to your classroom. How can you use this? How can you make it usable for you for your students? How can you engage your students—motivate your students? How can we make more people interested in science? And so that personally was more motivating to me, and more applicable to my experience in the classroom, whereas as an undergraduate, it was—you know—they were shotgun blasting general information to try and hit all of the majors, and as a very small percentage of us were education majors in physics, we really didn't get a lot—I mean, we got information, but we didn't get application out of it.

Kristi felt that the instructors were warm and approachable in both her undergraduate physics experience, and her training at River Falls. She did note however, that an essential component of the program at River Falls was the teacher-centered focus of the instruction. She provided a possible explanation for the more formal, though still friendly, atmosphere of her classroom:

In my undergraduate it was much more formal, especially in the introductory classes—the Physics 201—whatever the numbers were—but in the introductory classes, it was very formal, because there was ninety of us—or whatever—in those entry classes... At River Falls, it was always a warm, back and forth feeling between the professors and the students where we always felt very relatable and that topics could be brought up and ideas exchanged and, you know, “What about this?” And, “Could you explain that better?” And it was very easy flowing.

This also applied to the interaction among the participants as Kristi explains:

At the graduate classes, given that we were all teachers and stuff, it was very collegial--colleague to colleague. And, you know, very much open to working together, and “Here's my idea”, and “Here's what I do”, and “Have you ever tried this”, and at the undergraduate, it's—you know—you would have your study group of a few people, but a lot of times it was—you know—you weren't interacting with very many people. If there was 90 people in the class, you maybe knew 5, whereas at River Falls, you knew everybody in the entire room (laughter) and you worked with them.

Use in the Classroom Kristi also mentioned additional benefits that have carried over into her teaching as a direct result of her participation in the River Falls program:

I would just emphasize that it was a very rewarding program for me. It has greatly enriched my teaching of science. I think it played a huge role in the increase in my enrollment in the physics program at my school. It also gave me—I think some leadership background—because I started working and maybe teaching to other adults and teachers so that led me to doing other presentations with my colleagues at the high school and other schools as well. It gave me connections in other schools, so it networked me that way. That networking is huge, because I still keep in contact with different people from the program.

The training she received on the Vernier equipment in the program has also benefited her as she works with her students

I think I have a stronger connection to teaching at the high school level what an introductory student would need to be successful at the college level. By that I mean—even—you know, how you teach vectors, which is something I was doing today in class. So teaching students different ways to add and put vectors together. You know, seeing different techniques so they would see something similar to what they would see in college. Definitely a stronger lab component to my teaching, where students are getting labs that they will do again at the college level—or something very similar to them. Incorporating technology, because I think it was at River Falls where I saw the Vernier for the first time—the Vernier interfaces—and now, that’s what my school uses in our science department exclusively for data collection and doing computer-based labs or calculator-based labs.

The River Falls program used group interactions often as they covered course material, and Kristi has adopted this “Social Learning Principle” into her own teaching:

[We do] a lot of small group interactions and sharing with a partner, and those kinds of things, and then maybe coming back to some whole group discussion. It’s not a lot of “sit and get” kind of lecture stuff, but a lot of practice in the classroom, and then—where they get assistance from me.

Kristi did mention that she regrets not taking the Modeling course offered by River Falls.

She believes this method of delivering physics instruction would carry over effectively

into her classroom, based upon what she had learned about the method from other practicing teachers.

Introducing a New Unit When Kristi starts a new unit, she tries to use a demonstration, a video clip, or something relevant to capture her students' attention, and relate the material as much as possible to the everyday lives of her students. This is consistent with Redish Principles 1 and 2, the Constructivist and Context Principles. She went on to explain how she leads her students from what they know toward unfamiliar material: "I guess the technique that I rely on the most is just relating it to their daily life. Like, how does it make sense to what you see every day, or how can you explain it in your everyday life?"

And it is in these discussions about physics in the everyday lives of her students that she often uncovers misconceptions about the true nature of the phenomena being discussed. She explained how making the context relevant and repeating the exposure to the material were methods she used in an attempt to break down well-established mental models:

Um-hmm—oh yeah, definitely, it comes out with the misconceptions, and that just leads to more discussion and more investigation—more demos and all that kind of stuff. So, I think you have to give them some sort of framework though (laughter). You know if—whatever they're related to—you know, a lot it's, you know, when they are driving their car—what do they know about driving cars? What do they know about—you know, we were talking about relative motion today. I'm like, "Well, how do you know when you pass somebody?" You know, what does relative motion mean there? So, you try to bring it back to them—teenagers are very egocentric (laughter).

The Use of Multiple Representations Kristi believes that introducing concepts gradually, and using multiple representations such as graphs, tables, equations, diagrams, and sentences help students to better see the whole picture. Like so many other physics teachers, she notes that misconceptions can be difficult to change:

I think they're [the misconceptions] a little stronger. I mean, you might be able to convince one or two kids with just an explanation or one demonstration, but most kids will just go back to that previous background knowledge and say that the heavy one is going to hit first—or whatever the misconception might be. They're going to go back to that before they really, truly change their thinking. So it does take multiple methods and multiple exposures before they change those ideas.

Translating From One Representation to Another Consistent with the literature, Kristi also mentioned that training students to be able to translate from one method of representing data to another is no easy task:

It's definitely a challenge (laughter). They get into one thing, and it's hard for them to—I don't know if it's the maturity or the—you know—going back to Bloom's taxonomy—they're just not at that level yet, and so it's a lot of practice, and giving them a lot of practice in going back and forth between the different styles, or different types of ways to provide information. Because I know that on this first unit that we do on kinematics, they're pretty terrible (laughter) at going back and forth. But the next time we do it in forces, they're a little bit better. Then the next time we do it with energy they're a lot better (laughter) so I think they get better at it as they go through the year.

She admitted that in the past, she took translation skills for granted: “I guess in the past, maybe I thought, like they should know it already (laughter)—you know—why don't they know it? You know it's like, “C'mon you guys, you're already juniors and seniors, you should know this!”—You know? Can you read a graph? Can you find a slope (laughter)?” And she remembered that in her undergraduate exposure to physics,

translation was also an assumed skill that students came in with. What she has learned during her time in the classroom is consistent with the findings of Redish, Arons, McDermott, and others; Translation is a skill that most students do not come into our classrooms with naturally, it must be taught concurrent with the material being presented.

The Laboratory Setting Kristi admitted that in the lab setting, her experiments tend to be more “cook-bookie” than inquiry-based. She attributes part of that to the fact that she has not yet been trained in the Modeling curriculum. She is actively trying to change her lab style of instruction, but noted time as a critical barrier:

I would prefer that they would get the chance to do more exploration. Given the time constraints that we sometimes have to deal with, and making sure that they get a lab experience, and at least see some stuff related to the concepts, then—you know—you rely back on the cook-book model. I’m taking more information—you know—over the summer I did a Science and Inquiry class, and the AP College Board is doing a—like a seminar—webinar—on more open ended, or free response lab situations because that is a component of the AP test.

And while the students are gathering and interpreting data, Kristi wanders the room and makes sure things are running smoothly. When students ask her questions, she uses a Redish approach in handling them:

You know, I’ll try and turn it back to them, and relate it back to, “What are you seeing? What are—what’s your observation? What is your graph telling you? What is your data telling you?” You know, and turn it back to them—if I can. Or—you know, “Why don’t you talk in your lab group about what you see, and then call me back in a minute?”—You know, and have them discuss it more before they come—rely on me for the answer.

Accommodations Kristi calls herself fortunate to work in a district that is well funded. She describes her classroom space and equipment as excellent for her students.

Her administration is very science-oriented, and has been very supportive of her department. The district is implementing a brand-new grading philosophy this year, so much of what Kristi does with assessments, homework, and grading is up in the air right now. The new grading philosophy is an attempt to better assess and accommodate her students:

Our school right now is going through a transfer to standards based grading—or standards referenced grading—I guess I would call it. At the high school we're not truly standards based, it's more referenced. But anyway, they get a lot of in class practice with their formative pieces, and then their homework is only supposed to be stuff that they can do independently and that they should be very successful at—is what we've been told to do with our homework, kind of. And now, their formative pieces—their homework pieces are 20% of the grade, and their summative assessments—tests and major labs—are 80% of their grade... and I think the philosophy is right, because it will make the students better learning, because it's all about what they are learning, and removing the work ethic out of their grade, and some of those punitive things that teachers maybe put into their grades, like taking off points for late work—which—yes, you are trying to teach them a lesson about being timely with things, but should they have been penalized academically for it—you know—that separation I understand, and I agree with that philosophy. The putting it into practice—you know, how do I grade, on a 3-2-1-0 scale, or how do I feel about putting 80% of their grade on three tests that they have in a quarter? That's a little tougher to figure out this year.

So Kristi has a lot on her plate as she tries to tie her physics curriculum into an entirely new assessment strategy mandated in her district.

The Portfolio Kristi utilized an experiment wherein the students investigated factors that influence friction for her portfolio submission. Like Gary and William, Kristi felt that both the constructivist and context principles guided her most as she developed this lesson. She noted specifically that the open-ended nature of the laboratory setting at UWRF influenced her as she began to modify and design laboratory exercises for her

own students. Initially, Kristi felt she taught her physics classes more like math classes. However, as she became more comfortable with the material, she was able to utilize a more experimental-based curriculum. She indicated that “The open ended structure of [her] lab report [format] allows [her] to read and learn about what the student really knows about the topic.” She attributed this shift in her teaching specifically to her exposure to laboratory-based instruction in the UWRF program.

Closing Kristi began her career planning on teaching math, but her first job opportunity also entailed teaching physics. She felt that her math background was sufficient, but knew immediately that her lab background was weak. It was through a trial by fire that she truly realized she would need additional training to allow her to stop teaching her physics course like a math course, and she began to network. Her networking eventually led her to the River Falls program, where she eventually gained physics certification, and a Master of Science Education – Physics degree. She attributes increases in enrollment for her classes, increased leadership roles in her district, and the ability to retool her entire assessment system in large part to the training she received at River Falls. Like Gary and William, Kristi felt that her undergraduate physics experience did not adequately prepare her for her role as a high school physics teacher. She felt that the training she received in the River Falls program was much more applicable for teaching high school physics. She also appreciated the warm, collegial atmosphere that both Gary and William spoke earlier of. Kristi has found the network of teachers she has become a part of has helped her tremendously in her transition from math teacher to physics teacher. Her exposure to the teaching techniques presented at River Falls has

allowed her to acquire equipment and the knowledge to use that equipment for her students so that they will be better prepared for the rigors of college physics. Kristi is yet another teacher who began her career as a non-certified physics teacher, but was able to obtain certification through the River Falls program.

Steve

Background Steve is an experienced teacher from a rural Wisconsin school district. He is in his seventeenth year as a teacher, with the last sixteen of those years having been in Wisconsin. He teaches Advanced Placement Physics, Physics, Physical Science, and Chemistry. The high school, grades 9-12, contains about 320 students, and Steve reported that approximately 50% of them are eligible for free or reduced lunch.

Reason for Entering the River Falls Program Steve found out that he would have to teach physics if he wanted to take the job he currently has, and he was not certified to teach physics at the time he applied for the position. He explained that his area of emphasis in college was chemistry, but that he thought physics might be interesting to teach. He also knew that if he took the position, he would have to earn physics certification. In an interview conducted in the summer of 2010, Steve explained how he found out about the program being offered by River Falls:

Actually, it was one of their fliers that I had seen. I knew that I needed some credits, and it looked like it was—at first it was a good cheap way to get a couple of credits and for the state of Wisconsin, I still needed a couple different things to become physics certified, and it was a great way for me to get my certification. And after I took my first class there, that's where I really, really saw the value in the program and knew that I was going to finish out the program.

Preparedness When asked about his level of preparedness for teaching physics, he replied:

On a scale of 0 to 10, probably 0... I could read through the material, I could help the students with it, but I honestly, I didn't have a firm grasp of the physics concepts. There were a lot of things where I knew that "this was the equation we used, and this is how we used it", but I didn't really have an understanding of how everything related to one another until I started teaching it for a couple of years, and then especially through the physics program at UWRF. That's where I really started to really understand what I really was teaching.

Comparing the Undergraduate Experience to the Graduate (River Falls) Experience Steve took a couple of undergraduate courses in physics at a large Midwestern university before teaching physics initially, and taught for several years before entering the River Falls program. He commented on several differences between his undergraduate experience and his River Falls experience. He initially pointed out that the River Falls program stressed to him the importance of tying physics concepts together:

I would say that the courses I took in college, I did well in them, I studied hard, I was able to answer questions on the test about the concepts, but I didn't truly have an understanding of how the concepts related to one another, and how I could help other people understand those concepts. And I would say the UWRF program was one that really taught me how all the concepts related to one another, and how I could help the students understand those relationships a lot better than I had been in the past. It made me a lot more comfortable with what I was doing.

When asked specifically about the course structure, Steve commented on the class sizes and the availability of the professors in each program:

The River Falls program, we were a much smaller cohort, I think there were probably 25 of us in there, or something like that, and we had more one on one attention with the professors, and at [my undergraduate university], it was still a great program, but during our lecture session, we

would have 150 students in the lecture, and if you wanted to ask a question, you had to meet with a professor during his office hours and it wasn't as conducive I would say to really understanding everything. I could spit back what they spit out at me, but I didn't really have an understanding of what I was writing down on the page.

He went on to talk about the course content and once again referred to the individual attention received at River Falls:

It's really hard to compare the two of them because the courses I took at [my undergraduate university] were all calc[ulus] based and so we learned the calculus of physics, and I would say there was a lot more emphasis on how to do the equations and how to solve the problems mathematically, rather than concept oriented, which I think courses at UWRF were more about the concepts and the math was there on how to solve problems dealing with the concepts... At the UWRF program, a lot more attention was paid to me as an individual. At [my undergraduate university], it was still a very good program, but dealing with the large number of students that they deal with... they can't give you as much individual attention.

Steve also pointed out how the professors interacted with the students in the River Falls program:

I would say the professors at UWRF were much more available to us – I can't say my professors at [my undergraduate university] ever hung out at Bo's and Mine on a Friday night (laughter) I can't say that... And it was much more—since I was an undergrad in college it was more student professor relationship rather than—not really colleague-colleague relationship, but I felt more of that in the UWRF program. Our two professors saw us as the teachers and professionals that we were, and they saw how they could help us out as professionals rather than I am the professor and you are the lowly student.

Because the River Falls program recruited participants to assist them in gaining physics certification, the student body came in with a wide range of abilities and backgrounds with respect to their exposure and comfort with physics. Steve explained that the professors in the program understood that, and accommodated all participants:

I didn't feel like I was competing with anybody in the UWRF program.

We were all there to become better physics teachers. That was the goal for everybody there and our professors there did a great job of spending just as much time with the person that knew the material and wanted to learn extra, as with the person that was really struggling and needed the help... I think that was one thing that I thought [the major professor] did really well. He was able to sit down and take a difficult concept and show different people different ways to solve the concept based on—He got to know us really well... I feel like everybody got what they needed and what they deserved out of the program.

Steve was then asked to compare his lab experience as an undergraduate to what he experienced in the River Falls program. He noted that as an undergraduate, he spent his time in the lab “just taking down numbers and putting numbers into equations, and coming up with an answer, and that was it.” He noted that at River Falls, he “had to really figure out exactly what [the] problem was, how [he] was going to solve it, and then actually go about solving it.”

Use in the Classroom Steve explained several ways his teaching was directly influenced by the training he received in the River Falls program. He began by explaining his lecture method before his River Falls training:

Basically, when I started, the night before, I would sit down, I would read through the physics book, and I would say “Okay, this is what’s in chapter one, and this is what we have to do for tomorrow, and here’s how much we can get through, and here are a couple of practice problems, and I’ll try to work the problems in front of the kids, and then I’ll let the kids work”—and it wasn’t really conducive to the kids for understanding concepts so much. I think that they were able to sit down and solve a problem like I had solved a problem, but they didn’t really understand that there were many different ways to solve a problem, and they weren’t; the ones who were coming up with the ways to solve the problem. I was doing it for them.

Steve also noted that increased confidence in his content mastery has allowed him to make better choices about the homework he gives his students:

I'm much more comfortable with what I am teaching and since I have a much better grasp of what it is I'm teaching, I'm able to pick a better representation of problems that really represent the concepts that we are learning, and help me figure out if the students understand the concepts, and I think also help students understand the concept as they are going through the problem. So it's not just going through and doing all the odds in the textbook. It's picking and choosing, and adding a lot of my own questions.

And after becoming more comfortable with the content as a result of his time spent at River Falls, Steve explained that he is now able to let his kids be more creative now than before:

I'd say now it's changed there are times that—we still do a lot of problem solving and things in my class, and I kind of model a lot of my stuff after what we had done in our program... and I'm finding that the kids are finding really cool ways to solve problems that I hadn't thought about before. It's a lot of fun having the kids show each other going about solving the problems.

On a related note, Steve also noted that the collaborative problem solving strategies used by the River Falls program have carried over nicely into his own homework and laboratory exercises:

I have a lot of student collaboration, you know working with each other—kind of like what we did at River Falls where a lot of us would sit down and work through the problems ahead of time. And I get a lot more collaboration I think being more open ended than having students trying to compete against one another to see who is the smartest.

Introducing a New Unit Steve said that when he introduces a new topic to his students, he tries to present some sort of problem to them. He ties that problem in with what they will be learning, and he uses a group discussion format to generate ideas and

check for prior knowledge. He also mentioned that as he has spent more time in the classroom, he has discovered the importance of context in the introduction of a lesson. He tries to “come up with things [he] can present that are relevant to the lives of his students right now.” Steve also uses bridging when introducing new material where he “presents another question to them that may be similar, but doesn’t have exactly the same stuff... to see if they understand the concept.” He often uses whiteboards to assess student understanding, and attributes this technique to the Modeling program he was exposed to at River Falls.

The Use of Multiple Representations To make sure his students stand the best chance of success in his class, Steve said he uses multiple representations to present material such as graphs, tables, equations, sentences, and diagrams. He believes that “Everybody has a different learning style. Some people are visual, some people are all numbers, some people have to do different ways of learning the material, so the more ways you can present material and the more ways you can present problems, the better off the students are going to be.” And, consistent with the research discussed in chapter two, Steve agreed that misconceptions are quite robust in the minds of his students, he stated “There are certain circumstances where you can show definitively that their misconception is wrong, and students will not let go of it. They can do five different lab activities that show then that their misconception is wrong and they’ll still hold on to it.”

Translating From One Representation to Another When asked about the ease

with which his students are able to translate between these representations, Steve gave an answer consistent with existing research:

Oh, I've found that I have to teach students the translation (Emphatic). I had to be taught the translation. I mean, when we first started the program, I could solve an equation. You could give me an equation, and I could look at a graph and understand the graph, but I didn't really understand how the two of those things actually related to one another and for students, that's one of the things that I find they really struggle with is the relationship between an equation and a graph, and what the variables mean, and what the different parts of an equation stand for... That's something we spend an awful lot of time on, and I think by the end, students get a better grasp of it, but that's something that's pretty tough for them.

When asked if translation skills were taught as part of his undergraduate experience, Steve simply said "no," that was not part of his undergraduate training. However he said that River Falls "stressed translation a ton." And he believes that having his students be able to represent a solution in more than one way is extremely helpful to assess their understanding.

The Laboratory Setting The lab experience in Steve's classroom has also changed

as a result of his training in the River Falls program. He noted that using a more open-ended approach has allowed him to uncover misconceptions possessed by his students that might otherwise have gone unnoticed:

My first year of teaching physics was—the labs we did straight out of the textbook or straight out of the lab book that we got from the textbook company. And those types of labs were basically fill in the data sheet as you go along, and spit out an answer when you get done. Now, a lot of the labs that we do take many of the different concepts that we've been learning about and I give the students a problem that they have to figure out how to solve... [And] since the lab has become more open ended,

students are having to solve problems-- come up with different ways of solving problems, and in that process, I'm actually able to see where students' misunderstandings lie a lot more than I was able to in the other one. If you just give problems straight out of the textbook and give labs straight out of the textbook, they are either going to have a right answer, or they are going to have a wrong answer, but you don't really know what they're learning and what they're not learning. By being more open-ended, you really start to find out what their misconceptions are. And once you find those misconceptions, you can find ways to help students clear up those misconceptions. Otherwise, you can't.

Accommodations To warm the atmosphere in his classroom, Steve said that "[his] students can tell him that he is being a bonehead at any time" and ask for clarification when they do not understand. He said that he "tries to get to know everybody, and tries to get to know what things will help each one of the students out [because] each student is different. This is consistent with Redish Principle #4, the Individuality Principle.

In terms of formative assessments, Steve utilized a method he learned from the River Falls program that he described below:

With the tests I put together, I try to—I don't address each one of the students individually, but I try to put questions together and problems together that I think look at things from as many different aspects as possible so students can show that they understand things from as many different ways as possible. So, in that way, it kind of gives each one of the students an opportunity to answer stuff in their own way. And I think the answering five out of the seven questions kind of addresses that as well because some students are stronger in one area than another area [and] they can pick-pocket the question that their strong in.

Steve also commented that he would be open to students coming up with alternative ways of showing content mastery, but he has not had any students approach him with ideas since he became a teacher.

The Portfolio Steve was not able to submit a portfolio entry for this study, despite repeated requests.

Closing Steve, like so many others, started out teaching physics as an “out of field” teacher. The River Falls program made it possible for him to earn physics certification. Steve explained the importance of the way the program was funded when he first started:

I think that the program being offered with the grants that were available... I think that was a major reason why I was able to go through the program. I honestly don't know if I would have—I probably wouldn't have finished out the program if I would have had to pay full price for every single credit that I took. I absolutely would not have been able to do that. At the time, beginning teacher, struggling to pay all my bills and everything... I was looking for free credits out there and that was one of the things that brought me toward the program.

And after earning his physics certification in the River Falls program, Steve commented:

I just have to say that my time there was invaluable as far as what I've learned and what I've been able to help my students with now. I think that without having gone through the program, I think I still would have grown as a teacher, but I don't think my students would have the experience that they have now. I'm not saying that it's the best experience in the world or that I'm the best teacher in the world, but I think I'm a lot better than where I was when I started, I can tell you that.... I would like to see that particular program actually be part of an undergraduate physics-training program. I think that if you're going to teach physics, and you know you're going to teach physics in school, that would be the thing you should have before you actually hit the classroom and are able to understand a lot more things. Like I look back at my first year teaching physics, and I've talked to some of my students before, and I've had to tell them “I'm sorry.” (Laughter) “I'm sorry you had to put up with me for a year.”

Like William, Gary, and Kristi, Steve saw immediately the value of the pedagogical content knowledge being disseminated in the River Falls program. Both

Steve and Gary commented on how the program allowed them to see how various physics concepts relate to one another, and that they are not random, isolated ideas. Steve also lamented about the large class sizes present in his undergraduate physics experience, and as we have seen with both William and Gary, this situation is not at all unique. Like the previously mentioned case participants, Steve responded positively to the warm, collaborative atmosphere of the River Falls program. Steve took that atmosphere to his own classroom, and commented that his students seem to perform at a higher level when collaboration is favored over cutthroat competition. He also mentioned that the increased content knowledge he acquired allowed him to take his students to a deeper level of physics understanding. In fact, Steve mentioned multiple times that the River Falls program has allowed him to use a more open-ended approach in his laboratory curriculum, and as such, his students are able to come up with multiple ways to solve problems. Gary, using the Modeling approach, reported similar results. William, Gary, Kristi, and Steve all felt that teaching translation skills was essential in their own classrooms. They also felt that their undergraduate physics experience did not adequately prepare them for this skill, but the River Falls program was able to. Steve strongly felt that the increase in content knowledge, exposure to alternate teaching techniques, and the strong support network that he became a part of in the River Falls program contributed greatly to his growth as a physics teacher.

Jim

Background Jim is a sixth year teacher in a small, rural Wisconsin school district. The high school has less than 200 students, grades 9-12. Jim currently teaches high school mathematics and high school physics, although he has also taught mathematics at the middle school level.

Reason for Entering the River Falls Program It was a restructuring of his school district's science program that ultimately led Jim to the River Falls program. The district decided to try a "Physics First" approach wherein all freshman level students take physics, to be followed by chemistry, biology, and then whatever advanced course they chose to take as seniors. This restructuring allowed for an opening in their science department for someone to teach half time math and half time science. Jim assumed this position.

Jim knew he needed to add physics to his certification, and explains that other staff members in his district had participated in the River Falls program:

We had a couple of teachers here at [my district] that had been to the program before. One who completed it right about—one of the first years they had it I believe—in the '80's maybe. And he had been here a long time—taught for many years, and he went through the program—that was how he earned his physics certification. And then another teacher who came to just finish up some credits and spent a summer in the program at River Falls, too. So I knew a little bit about it through that. I spoke with both of those guys, and just sort of found out through doing a little bit of research that that was one of the—the place to go in the state as far as a physics Master's program, so that's the way I went.

Preparedness Jim had one course in physics as an undergrad before attempting to teach the subject. He talked about his level of preparedness going into that first year:

[I was] Not very well prepared at all (laughter). I hadn't taken physics—I took a physics course in college and in high school... and I hadn't hardly thought about physics since that time, which would have been six or seven years later... And I—to be honest with you really—was kind of going in with my—trying to keep my head above water... you know, it's my fourth year now, but like I said, my first year, I was sort of on my own, I didn't have another physics teacher even in the building to bounce things off of, so I was sort of just following the textbook that I had, the curriculum that was sort of in place for me, and realized after a year that there's a lot of other ways to do things.

Comparing the Undergraduate Experience
to the Graduate (River Falls) Experience Jim has just recently earned his Master of Science Education – Physics degree from the River Falls program, and has identified some key differences between his undergraduate experience in physics, and his experience in this physics teacher-training program:

Oh, they were definitely different. The undergrad course I took was pretty much fulfilling a science requirement. My degree was in math, I was a math major, and didn't have a minor, so that was my main focus. I took the physics to fulfill the science requirements, and it was, you know, mostly a lecture. The River Falls experience was a whole different deal, with—you know—I think the biggest thing was just being with colleagues the entire time. Having, you know, a room full of teachers with varying levels of experience and then I was—you know—I taught three years of middle school, had no science teaching experience at all, and we had everybody there from somebody like me who was a newbie to people who had—you know—25 years of experience and were just taking credits to learn something new, and people who were pursuing a Ph. D. and things like that, and—just being around all different types of people but all of whom who had kind of a similar goal in mind. That made it huge, because we'd all kind of help each other out, and things like that. It was much different I felt like.

He went on to comment on the role of the instructors, and the importance of the social setting in which the program occurs:

The instructors are much more able to be more hands on with you. I mean, we have a group—we had a group of about twenty each summer I was there—to be around a group of about twenty and to be there every day for anywhere from three to five weeks, you really get to know them very quickly—especially in the lab setting—not even just that—in the lecture too—with homework and everything you do—I mean they are very accepting and very willing to work with you and like I said, being the new kid on the block, I needed a lot of help, and the people there were always outstanding, whereas in an undergrad situation, you know, I’m in a huge lecture with a ton of people and the lab setting is different, too, and we were in the lab every day for the whole time I was there, so—much more hands on, and much more—I mean, the men and women there—the professors will spend hours with you if you need it, and it’s really great. It’s really helpful.

When asked about what he valued about the program, Jim lumped the essential components of a successful program, his values, and his ability to carry things over into his own classroom into a single answer:

Just the hands-on nature of it is fantastic. I learned so much that first summer about things that I can apply directly to the classroom. I mean, they have a great balance between—you know—first the content, learning about physics and all the things you need to know—that background knowledge you need to have. But then also how to bring that to my classroom and how to have students learn that from me—all the ideas—the demos, the labs, the little hints—and it helps again being in a room full of teachers when something would come up—you know, somebody would say, “I did it this way”, or “This is what I do—this is what I talk about.” Just being able to move it towards my classroom was really the whole point. I mean, that’s why I’m there, and it’s so easy to do, and so helpful that—to me, that’s the number one advantage of the program.

Use in the Classroom Jim mentioned rigorous nature of the program, and began his discussion about the challenges of simplifying the material to make it appropriate for freshman students:

For me, I guess—I don't know—the interaction—dealing with kids—you know, I'm in a rural setting, and like I said, I'm teaching physics—the first couple of years anyway, it was just to freshmen, and so the base of background knowledge for them was not as deep. And I guess just being able to try to simplify things maybe a little bit more than what happened when I was sitting in a room full of teachers learning about physics. You know, there's a lot of things that are taken for granted, and rightfully so, because you're in a room with a bunch of teachers—science teachers—and people who are very experienced, whereas I'm dealing with freshmen who are right out of middle school, and – you know—so there's a lot of little things about relating to the kids that I guess I do a little bit differently. But other than that, as far as the content, a lot of what I do is pretty similar I think.

Introducing a New Unit Jim explained that he tries to catch the students' attention and “engage them with something interesting” whenever he starts a new lesson. He pointed out that in his classroom, leading students from the familiar to the unfamiliar is an incremental process. He explained:

I guess the first thing is to try to keep it—try not to make it as big of a leap as possible. If we're talking about acceleration, we should be all ready pretty versed in velocity. And so to try to relate those two as much as possible while still pointing out the differences, and the importance of them—and again, to make it familiar to them by giving them something real to hold on to—or to look at—or to—whatever.

Here, Jim is utilizing what Redish referred to as bridging, that is, using something familiar to make a connection to something unfamiliar.

Jim was then asked about misconceptions his students have about physics phenomena. Jim agreed with the research when he says that misconceptions possessed by his students are very robust, and difficult to change. He mentioned a familiar example to most anyone who has ever taught high school physics:

Oh, they are definitely stubborn. (Laughter) you know a lot of kids that think they know it all, and have all the answers, and sometimes they don't

want to let go of—you know, the same exact example—I’ll drop the two water bottles and – you know, it’ll be one of those informal things, I’ll just drop them and one will hit a fraction of a second earlier—or at least they’ll perceive that it did, and they’ll say, “See, it was that one,” and they won’t (laughter) want to necessarily let go of it. Then [they will] come up with reasons why it was a fraction of a second faster. So that’s often tough to overcome, but usually, I mean you just have to kind of stick with it.

And when asked specifically what he meant by “sticking with it,” he explained methods he uses that seem to align with Redish. In the passage below, specific Redish principles have been added in parentheses following the strategy Jim is explaining:

Often I guess, I mean, again, the more different ways you can show a kid something, the better off—the more likely you are that one of those ways are going to click. So I try to come up with a different example—I’ll always try if I can to relate it to something that I know that he might understand better (Constructivist, Context)... A lot of times, you know, kids learn better from each other, so sometimes getting the kids together in groups and doing some kind of an activity or even a lab or whatever—that will get them—you know they can kind of see it and explain to each other what’s going on better than I can (Change, Social Learning). So, that’s one thing we do a lot of—a lot of small group things, short little activities, rather than big labs. And trying to give them as much time as they can—you know—experiencing it with their hands and their eyes as much as with their ears and with me (Individuality, Social Learning).

The Use of Multiple Representations,

and the Necessity of Translation Skills Like so many others, Jim agreed that

using multiple representations such as graphs, tables, equations, and sentences are all necessary to convey physics information. He also explained that his students struggle with the ability to translate from one representation to another. His experience is typical of others reported in the research:

I think it’s—for me, it’s usually a struggle... Just today actually, we were graphing—they had done two graphs, one of position versus time, and one of velocity versus time, and we were comparing the two, and trying to get them to see that the slope is equal to the velocity at that moment, and that

was a big leap for them. They didn't quite—most of the kids I don't think quite grasped that right away, and that was a big leap. So to go from seeing a car roll across the floor to okay now it's on paper on the graph, and okay great, I made a graph, but what does it really mean? That's a big leap for them. Yeah, it is tough to bounce from one thing the other, and to get them to make all of those connections...

Jim commented that his undergraduate physics coursework did not teach translation skills. In his mind, it was assumed that the students either had those skills coming in, or they learned them on their own. When asked about how River Falls addressed the translation issue, he felt quite differently.

[Learning to translate was] Much more clear. For one, I think there's a little bit more time, especially in the lab setting, to get help with analysis and things like that. You know, I spent a lot of those lab days where you're supposed to start at 1:00 and then set up from one to four—I was there from five to six a lot of times (laughter)... And you know, it gets to be a long day, but at the same time, I mean I always came out feeling like I knew it, and for me, that was big. And a lot of that extra time was, "Okay, I need somebody to explain to me why we graphed this, what am I looking at here, what is the slope, what is the line, what do those things mean?" And that was much easier for me to pick up when I had the three or four guys that were there to help me with it. Yeah, that was—much more access to that type of help specifically.

The Laboratory Setting To assist his students in learning the art of translation, Jim uses the Modeling technique, which was explained in detail in Chapter 2. He explained that he relies heavily on whiteboard presentations by his students in which they gather data, construct a graph, and then explain the parts of the graph such as the slope, the y-intercept, the area under the curve, and the equation represented by the graph. The explanations are in both written and oral form, consistent with the Modeling approach, and research seems to indicate that this type of exposure to physics greatly aids in the acquisition of skills related to translation.

Accommodations Jim is also in a unique situation in that the curriculum in his district is structured so that every student takes physics as a freshman, and then has the opportunity to take a more advanced version of physics as a senior. As a result of this, he has been able to team teach the freshman class with a special education teacher, and he commented on how he feels this partnership has enhanced his ability to reach his kids:

“Well, one of the big things that’s helped me is our special ed department. I’ve team taught every year I’ve had this. I’ve team taught with one of the special ed teachers. And you know, they have a ton of just different—graphic organizers, or little activities that can take five minutes at the end of class that we can do to just assess what we learned that day, and what we learned yesterday... We’re a small district, and one of the things that we strive for is 100% inclusion of all of our students. And so I think out of the freshmen there’s only one or two freshmen in our district that don’t have my class—that are pulled out for a separate science class. So there’s a lot of modifying activities—you know, taking a concept and saying, “Okay, what does this student really need to know?” I’ve had autistic students and things before and you know, done a lot of modification. And like I said, it’s been a help, because I’ve had a special ed teacher with me for at least one section of physics every year. I’ll be honest, a lot of that falls on them, but it’s something that we’re constantly doing. And often what works for those students works very well for the other students, and even at the start of the year, you know, going through basic metric conversions—my colleague had a different chart on a different sheet of paper that for whatever reason the kids thought was 100 times better than the one I gave them (laughter). So you know, she was able to pass that along, and it not only worked for the four kids that she meant to pass it on for, but you know, the rest of the class ended up liking it too, so that’s something we’re always trying to do.

Using the team-teaching approach and striving for 100% inclusion of all freshmen has caused Jim to explore Redish’s Individuality Principle maybe more so than the typical high school physics teacher.

The Portfolio Jim was not able to submit a portfolio entry for this study, despite repeated requests.

Closing It was the reputation of the program, and a shift in district philosophy that led Jim to the River Falls program. Jim, like the four previously mentioned case study participants, felt he needed additional training in physics education to take him to a higher level as a teacher. He, like all of the others previously mentioned, enjoyed the collaborative, non-threatening nature of the instruction provided by the program. Jim specifically pointed out that he liked the diversity of the people within the program, because he felt that each of them had something both unique and of value that they could contribute to the student body as a whole. He was the only participant who specifically pointed this out. He felt the most important aspect of the program was to find ways to carry over what he was being taught into his own classroom. Jim, like William, Gary, Kristi, and Steve, also saw the value of this program early on. In fact, Jim commented that the program had a positive reputation in his school district even before he started working there. He felt the pedagogical content knowledge he gained was extremely valuable. Because of his training and the unique approach of his administration, nearly every ninth grade student in the school where Jim teaches has the opportunity to get exposed to physics.

Pam

Background Pam teaches in a large, urban district in the Mountain West. She is in her eighth year, and is currently teaching in a school with a grade 9-12 population of approximately 1200 students. Her population is very diverse. Approximately 75% of the students are not Caucasian, and Pam notes that they come from places such as Polynesia,

Africa, Bosnia, Mexico, and several Hispanic countries. Because her students come from so many different places, speaking and understanding English is an issue at her school. On a survey administered to Pam for this study, she indicated that between 30-40% of the students in her school have limited English proficiency. She also indicated that over 50% of them are eligible for free or reduced lunch. Finally, she also felt that the achievement level of the students in her school was “far below” that of students in other schools within the state she teaches in.

Reason for Entering the River Falls Program Before coming to this district, Pam taught biology, honors biology, and integrated science. In her current district, she teaches biology, earth science, environmental science, and astronomy. She will be teaching her first physics course this upcoming school year, however because of the unique nature of her population, her physics class will not look the same as a “typical” high school physics class. In an interview conducted in the summer of 2010, she explained her situation:

I’m going to be teaching physics next year—this upcoming academic year. And I’m going to be teaching—it’s not a mainstream physics class. It’s going to be—I just finished my ESL endorsement—so it’s going to be physics for English language learners. [My city] has a lot of refugees that come in, so they’re sort of tracked into a different—I guess track—of taking science classes. They’re not really in like—I mean, some of the kids in the ninth grade level don’t even know what the three phases of matter are. So, I’m going to be getting students that are in their third year—they’ve been there at least three years—and they’ve been recommended by their previous science teachers to take physics.

She went on to explain that the seed for creating a course like this might have been planted prior to her relocating to this district:

Well, when I was in Milwaukee, I saw that River Falls was offering some physics courses—some grad classes in physics, and that it was part of a

grant. And so, I thought that it would be really fun to teach physics or at least take some classes on it—because my major is in biology—as well as the life sciences... So I started taking those classes and I just realized I could just continue with the program—you know—the Master's program. So I'm excited—there's definitely a need for—This is the first year my school is going to be offering ESL physics or ELL physics because a lot of the teachers haven't been—they're not endorsed in ESL.

She commented further about the impact of the grant funding on her decision to apply to the program:

The main thing that attracted me to the program was the fact that it had a grant associated with it and the first year, I got a telescope, I got a ton of materials for free through this grant. I was kind of sad to see this effective program to train physics teachers didn't receive the grant the next year. And I felt like having that equipment was good enough, but I thought it was just kind of a shame that it didn't continue on. But I thought it was really great of the professors to actually apply for these grants and effectively recruit teachers into things that would make them interested in physics. That's how they attracted me.

Pam is not currently certified to teach physics, but her survey response indicated that she intends to become certified and also earn her Master of Science Education – Physics degree through the River Falls program.

Preparedness Pam indicated that she feels “pretty prepared” to teach high school physics because of her experience as a physical science teacher, and she also notes that there are several experienced physics teachers in her school that have offered their assistance.

Comparing the Undergraduate Experience to the Graduate (River Falls) Experience When asked about her undergraduate physics experience, it was discovered that Pam had actually completed her undergraduate

degree at River Falls as well. Despite the fact that she had many of the same teachers in both her graduate and undergraduate experience, she did note some key differences:

Yeah, I think for the undergrad, they were just going through very basic stuff, and they're going very sequential. And for the grad part, I felt they were covering—they were spending more time in areas where I felt that teachers have a hard time teaching the kids. And so I felt we spent a lot of time on certain areas of content where we needed to—where we needed a little more emphasis and we needed a little more help in maybe being more articulate or finding new demos—more demos to provide an example for certain concepts—more difficult concepts.

She also mentioned the community aspect of the graduate program:

I think it was a good opportunity for me to collaborate with other teachers that teach it. I get to hear how creative they are and how they structure their class, and what kinds of activities that they do. It also helped me sort of—I think the program is just amazing. I think that the way that they have it set up—it's just such a community. The teacher that teaches it teaches it every year—at least when I was going through it—the same lab person—and they really focused on progress. And they also had volunteers from the community that have taught physics help. And you were in a dorm with all the other students, and it was just a really great experience to learn—an intensive experience to learn physics and also to become a better teacher.

And with respect to the instructors in the program:

The teachers were really—my teachers were very helpful and collaborative, and they take ownership over making sure everyone understood and—yeah—it was a positive learning environment—a more positive learning environment than at the undergrad level.”

She also noticed a difference in the availability of the instructors in both programs as well:

I felt like we were always with them, like in the summer. So I felt that if I really had a question that I wanted to ask one of my professors, I would be able to ask them. But I felt like in the undergrad setting, you're not with them. You're only with them for an hour—however long lecture is. And there's not a lot of free time to ask questions and if you need to, you need to ask outside of class... But during the summer they didn't need to have

outside office hours because you're with them for like six hours of the day (laughter). So if you didn't feel like you had time, then, I don't know, you're pretty ridiculous (laughter).

In addition, Pam commented on the difference in the lab format between her undergraduate and graduate experience:

I felt like there was a huge difference. I felt like in undergrad the focus was more towards basic understanding...like it was more for getting the experience and understanding the concepts, and it wasn't so much a formalizing of your understanding I guess.

And her graduate level experience:

Well, I feel like it was much more inquiry in college at the grad level. Like I had to come up with—I really had to sit down and think and analyze what the data meant, and there wasn't like a format to the analysis. Like I had to pick out specifically what I learned and what the results mean, and I had to calculate error and uncertainty of every instrument that I used and incorporate that into my results. And I don't remember doing that at the undergrad level.

At the conclusion of each course, the River Falls program has a sharing session where each participant shows the class a demonstration, or some sort of application of the material being covered in the course that can readily be applied in a high school classroom. Pam commented on the sharing session experience:

I thought they were amazing. I was really blown by how some people really changed their classroom into not only learning science, but doing science. And I just imagine some of these classrooms—It's like you walk in and it's set up for kids to see science and participate in science and some of the demos are just fantastic—what some people were able to construct—you know—this isn't something that you buy from Carolina—these teachers constructed some of these physics apparatuses by themselves and I thought that was really cool. I think that's a really great way of teaching—is by doing and showing and having them see.

Use in the Classroom When asked about what she has been able to use in her classroom as a direct result of her time spent in the River Falls program, Pam brought up several items:

I think I've been able to play with how I organize and facilitate my labs... I think that they way that [one of the instructors] structures his lab classes is awesome. And I think that he walks a fine line between showing students what to do and why, and helping them along the way so they can—the students can actually grasp the concepts through the experiment itself, and also how to formalize their lab write-ups... I go through that with [my own students] and talk about quantitative data, qualitative data, being precise and accurate, and I talk about error, and I think those are the things that I don't think kids really think about. They just want to see the water turn red, or they want to see something explode, or something like that. But really analyzing the process and the results, I think is looking at labs in a different way—I think I've tried to incorporate into mine—into the lab portion of my class.

Pam noted that this was not the way lab sessions were conducted in her undergraduate experience, and also pointed out the struggles that her students have with learning in an inquiry environment. The points she made are consistent with those made by Redish and others in chapter 2:

I've always had a hard time like really having the kids inquire, and associate that inquiry because I think kids come in with varying levels of background information, and expecting them to make an inquiry about something they have no background knowledge on is defeating and difficult. And I have to work on that myself—like scaffolding as I'm teaching a certain concept and giving them enough secure background knowledge that they can actually come up with an educated hypothesis or prediction. [The River Falls program] gave me something to work from when I was working with my kids on sort of structuring the lab component of my class.

As a specific technique, Pam mentioned Modeling. She pointed out that she did not take a Modeling course at River Falls, but rather at another Wisconsin university. However, her instructors were the same people who taught the Modeling curriculum at River Falls,

and this is the same Modeling curriculum developed by Arizona State University and discussed in detail in Chapter 2:

Modeling in physics—which is something they learned in River Falls—but I thought that program was really great, and the way that they conducted a class I thought was really great with white boarding, and collaborative work within the students. I definitely, right after that summer incorporated that right away. They gave us all the materials. They gave us white boards, and examples that we went over and over again during the summer sessions, and I just felt really comfortable with incorporating Modeling after a lab and discussing the lab results in class using white boards, so that was a pretty effective tool.

White boarding involves putting all of the data, graphs, analyses and conclusions on a large white board with erasable markers, and presenting these findings orally to class at the conclusion of a lab activity.

Pam did mention that due to the unique nature of her student body, she did not feel that she would be able to incorporate the rigor from the River Falls program into her classroom, but she did feel the inquiry aspect of her training would carry over quite well.

Introducing a New Unit Pam described how she typically begins a new lesson, and, consistent with existing research, she mentioned that misconceptions about what is being introduced inevitably arise:

I try to do demos. I try to do labs, and I'll do the lab, and then we'll discuss it. So they'll do the activity and some sort of phenomenon—what happened—and then we'll discuss it. And we'll say, "Well, why did this happen?" And I think for physics--whenever our Master teacher—that's exactly what he does—everything—in every class, he'll do a demo, and sometimes it'll be just a piece of the demo he did the day before, and the kids will write down the wrong answer, and as they go through, they'll write down something incorrect, and he'll just go over it, and over it, and over it, because physics, I think has more misconceptions than any other science, I'm sure.

Pam believes that by exposing students to unfamiliar material multiple times and in different contexts, misconceptions may be able to be addressed:

I think for physics I would do—I would show them—I would give them examples of real life observations... And for physics though, I think it's more meaningful if you show them—if they see it with their eyes. And even then, it's probably not going to stick, because misconceptions seem to—they just—it's something that always will stick with them. But just kind of showing them over and over and over again in different contexts will hopefully show them that it is a myth or that it is a misconception.

The Use of Multiple Representations In addressing these misconceptions, Pam mentioned that she uses several different methods of data representation, such as graphs, tables, equations, diagrams, and paragraphs to describe the course content.

Translating From One Representation to Another When asked if she felt that students could easily translate between these various representations, Pam noted:

No, I don't. I think that—well, from the data that I've heard—that I've seen, students have a difficult time interpreting graphs and tables and diagrams. And they have a difficult time finding relationships between variables in those contexts. I think with numbers, even more if you're not a math person. I think that just seeing numbers would be discouraging and frustrating. I think those are difficult, but I think that they're very useful, and they're very—I like looking at diagrams, and I think that if you show them how to look at it—if you show them to be comfortable with it, I think they can be extremely useful as a setting after reading through the text.

Accommodations To assist in her students' learning, Pam relies heavily on the Individuality Principle developed by Redish. Because of the diversity in her classroom, Pam has developed some very creative ways of assessing the achievement level of her students:

Usually those students are very creative and they like to manipulate things, so I've—in the past, like one student I made him make a model of a green home, and so he incorporated, like geothermal energy, and solar paneling, and he made this model of a home that is energy efficient, and I gave him credit for that. I accepted that as points for the things that he didn't finish.

Pam mentioned that she is open to using alternate forms of assessment for students to demonstrate mastery of the content being presented in her classroom.

The Portfolio Pam submitted an assignment on vectors. She reminded me that her physics course was designed specifically for Limited English Proficiency (LEP) students, and as such, it may look different than a more traditional course. Unlike the other participants with several years of teaching physics in a more traditional fashion, Pam felt that the social learning principle factored most prominently in her design of this lesson. Like Gary, Pam specifically mentioned aspects of Modeling that she felt greatly assist her students in learning both physics, as well as the English language. Pam explained that “Modeling uses whiteboards [which] offer the opportunity to collaborate in small groups to present a concept to the whole class.” She explained further that students do this after every laboratory exercise to “regroup, reflect, discuss, analyze results, and make conclusions on the main concepts of the lab experience.” She mentioned just how difficult it is to work with students trying to learn both physics and the English language when she said “Even though my other content courses have [many more] kids in them, I often feel mentally and physically exhausted [in the LEP course] going to individual groups and clarifying concepts [for them].” She also recalled being “very intimidated” by the UWRF program her first year because of her life science background. However, she went on to mention that the social learning principle was

what ultimately minimized her initial fears about the course. She mentioned that the collaborative nature of the problem solving and laboratory discussions put her mind at ease, and she decided to utilize a similar strategy with her own students who, because of their LEP, often share these feelings of fear and intimidation in the science classroom. This is Pam's first year as a physics teacher, and she is teaching a very unique population of students.

Closing Pam began her career as a biology teacher, but became interested in teaching physics because a grant became available for her to try out a physics teacher-training course. Despite feeling intimidated initially, once she became involved, she liked the way the program was structured, and continued taking classes. Pam, like the five previous case study participants, also commented positively on the collaborative, non-threatening nature of the program. Pam commented specifically on the physics sharing sessions as being especially helpful. She valued these sessions because she could see what other teachers were developing and deploying in their classrooms, and ask them questions about their curriculum. Like Gary and Steve, Pam felt that the open-ended nature of the lab exercises at River Falls allowed for higher order thinking to take place. She intends to gain not only physics certification, but also a Master of Science Education – Physics degree through the River Falls program. As a result of her participation in this program, she is starting a physics course for Limited English Proficiency (LEP) students in her school, which houses a very diverse population. This, she hopes, will make her students more science-literate as they graduate and journey out into the real world.

Dee

Background Dee is a ninth year teacher in a high school of about 400 students in Wisconsin. Her district adjoins a much larger district. Dee is different from the other case subjects in that she has never actually taught physics. In the past, she has taught biology, algebra, and remedial math. She is currently teaching chemistry and a physical science course primarily to ninth grade students. Dee is not yet physics certified, but does intend to gain certification, and complete her Master of Science Education – Physics degree in the River Falls program.

Reason for Entering the River Falls Program Upon starting her job in the district she currently teaches in, Dee believed that she would eventually be taking over the physics position from a teacher who was nearing retirement. In an interview conducted in the summer of 2010, she explained: “When I started my Master’s program in physics, I envisioned that someday I would take over his classes—His physics and his chem. classes. So I knew I would have the chem. licensure, it was the physics licensure I was missing. So when I started the Master’s, that was the goal—was to get that physics license so that I could teach physics.” She went on to explain that due to financial hardships within her district, they decided to staff the physics position differently than what they had originally planned on. Dee said that she someday hopes to teach physics, but right now, her teaching load is primarily chemistry, and ninth grade physical science.

Preparedness When asked how prepared she would have been to teach physics, Dee expressed her concern:

Oh, that would have been tough (laughter). I think—my undergrad was from River Falls, and so I did have some physics as a part of my chemistry major, but going in and like teaching physics right away in 2001 on, like an emergency license, I would have been very overwhelmed I think—with just the content and trying to get the labs, and yeah—it would have been overwhelming (laughter).

So Dee completed her undergraduate studies at River Falls as well. She is currently in the process of completing her final project for the Master's degree.

Comparing the Undergraduate Experience

to the Graduate (River Falls) Experience Dee felt that her undergraduate physics

experience was quite similar to her graduate experience. This could be due to the fact that the same instructors were responsible for courses in both the graduate and undergraduate level courses. She felt that the course structures were almost identical, however she does note a difference in the lab aspect of each program: “The lab I felt was a lot more—they wanted you to kind of do a lot more on your own in terms of writing up the lab reports. Like, with undergrad, they would walk you through it more, I think. The labs for the Master's stuff to me were really hard—Harder than the lecture part.”

In terms of approachability, she felt that she was “looked at as more of a professional” in the graduate program. She went on to say “I felt more comfortable talking to them, just because I felt more on the same level--Like, we were all trying to get through it together, where in undergrad, it was more like, “Here's the stuff.”... So, I don't know, I felt more comfortable—definitely—in the Master's program.”

Perhaps because Dee orients her curriculum to ninth grade students, she did experience some frustration with the material presented in the River Falls program. She

explained that she felt she did not learn teaching techniques for her students that she was hoping for:

I felt like I didn't get a lot of new science techniques—kind of stuff. You know that Modeling was pretty much the only one that was specifically science techniques type of stuff. Like now, I'm working with a professor at [a nearby university], and he came into our school district, and they're doing things with the communities of learners, and like more teaching stuff that I wish I would have got through the Master's program, that I don't feel that I got. I feel it was a lot of content, and it was physics—a lot of good physics, but the teaching part of it, I feel I really missed out on-- Like new science specific techniques that I'm not getting-- Like we're really pushing in our district more inquiry—Like how to set up inquiry labs, and how to get the kids—Like this is the emerging push in science is all this inquiry stuff, and I never got any of that over in the Master's program. So I guess I would have liked to have seen that kind of a thing presented.

She went on to explain that though the level at which the content was presented in the program was a little too high for the students she works with, she did find that the time spent networking with other teachers in the program was valuable:

What I really liked was the teachers who teach ninth graders, or eleventh graders, or eighth graders, who would bring labs and ideas to the table, and that would help me change how I was teaching—Like, this is what they do in their room—I'll try that in my room—see if it gets the same results—so, that stuff really helped me. The content itself, I felt was good for me personally. I loved learning it. But it wasn't going to help me in my room, because it was too high above where most of my students are.

Use in the Classroom When asked for specific examples of how she brings the content down to the level that her students are at, Dee explained a technique she used for exploring electricity:

We do electricity, and so I talk about circuits, and we talk about circuits, and they pretend to be the electrons, and I give them Tootsie rolls, and they walk around the circuit, and then I say, "Okay, now we're going to increase the voltage, how are you going to act if I increase the voltage?"

And I'm going to give you more Tootsie rolls and that means more power in the battery...

She went on to explain that she is trying to incorporate more inquiry-based activities in her classroom:

...Getting up and moving around, and being able to be a part of the circuit—they like that. And like I said, I'm trying to incorporate more of the—you know—making your own labs, and like inquiry stuff like I've—every unit I try to have something like where they have to write their own procedure, determine what's the manipulated and responding variable, make a graph that looks at those things, analyze their data, and as a science department, we're trying to come up with big projects for every class that go into inquiry, like you make observations and then you have to come up with your own problem, and how you're going to solve this problem, and those kind of things that are related to the content. I guess those are the things that I've been working on that I think are successful, that are helping our department move in the direction we want to go.

Introducing a New Unit Dee was then asked to explain how she typically begins a new unit. She mentioned that her methods were undergoing a transition. Initially, she would “present information, and then have them do a lab.” But as she has explored the possibility of using a more inquiry-based approach, she has experimented with having the students explore with the lab equipment first, having them formulate questions, design an experiment, and then carry out that experiment. Dee is currently exploring the idea of “activity before content” which is completely opposite of her self described “traditional method” of instruction.

To lead her students from what they know toward what they don't know, Dee relies on real life examples, consistent with Redish Principle 2, the Context Principle. Her process involves starting out with something familiar to her students, and with the use of guiding questions, bridging them toward unfamiliar concepts. She does mention

that misconceptions often arise during this process, and that those misconceptions can be difficult to break through, but her method of dealing with them is consistent with what the research says seems to work, direct, personal observation: “I guess I would say like a demonstration, or actually seeing some kind of a demonstration of that concept helps. It doesn’t necessarily go the whole way, but it helps go further than just—“This is why, blah, blah, blah—explain it to you, blah, blah, blah.” Because if you can show them somehow, then they are more apt to believe it I think, than if you just say it to them.”

The Use of Multiple Representations In order to convey information to her students, Dee believed in using multiple representations for the data being discussed. She explained further:

I probably favor graphing. I love graphing, and I don’t know if it’s just a science thing, or a chemistry or a physics thing. I tend to like graphs, so I usually will have some kind of a graphic representation. And then, I like to put the mathematical equation in there. I also like to use sentences like describe. They seem to be the best with what’s going on—describing it with sentences.

She also mentioned the difficulty that her freshman students have with mathematical concepts:

We’re doing about density of water—we took different amounts of water and the class found the mass and the volume and I had them graph it. And then I was like, “Now you need to make trend lines”, and about two kids of my class were like, “What?” And then I was like, and then we’re going to find the slope, and of those two kids, only one was like, “Oh yeah, slope.” And I’m like, “Oh.” So I think with ninth graders, it’s a little bit too far mathematically for them to do the slope. Now with a physics class if I was teaching physics, I would absolutely do that. We would do slope, we would put it on Excel, I would add a trend line, we would do all that kind of stuff.

Translating From One Representation to Another Consistent with the research,

Dee explained that her experiences with the students she works with have shown that the ability to translate from one type of data representation to another is very difficult: “I think it requires a lot of attention, especially if you think of the kids that are not mathematical or not science oriented. Going from a description that is just words to something that is a picture with numbers and points and—I think that’s a hard leap.”

Dee also said that she did not feel that her undergraduate physics experience stressed teaching translation skills as material was presented. She felt that “It was just something they [her undergraduate professors] assumed you could do.” But when Dee was first exposed to Modeling, she felt this program handled translation differently:

That was—I thought that was a really good example of how to do that. I really like that class looking back on it because it only taught concepts—it taught you how to teach the concepts in a way that kids at that level could understand it. I haven’t used it, so I’ve kind of lost some of the nuances of it. But I remember liking it and going, “Oh, this is a great way to teach a concept.”

The Laboratory Setting When asked about how she works with students in the

laboratory setting, Dee once again explained how her instruction is in a state of flux:

I guess it kind of depends on the lab exercise and where we are in the year. Because my first lab with my freshmen—It’s a cookie-cutter kind of lab, where it’s just like—we have—you know, you follow directions, you write down the results, but as the year progresses, we do more stuff. Like this next lab that I’m going to be doing with my ninth graders is going to—just practicing manipulated and responding variables—and we’re going to do—like throwing airplanes to see how mass and volume — things that they can measure—how they affect each other in a paper airplane. And typically I would start out by giving them a problem, but because I’m trying to do more inquiry, this year, I’m going to try—and have them play with the paper airplanes first, and then I think we’re

going to develop a problem together to look at variables, and things like that.

Accommodations Because she teaches a ninth grade course, Dee has a wide range of abilities within her classroom. She has had to modify instruction and assessments to address the needs of her students. She cited an example of how she addressed a language barrier issue:

I had a—two years—was it three years ago? I had a kid who came from Mexico. He got here on a Wednesday and was in my class on Thursday, and spoke no English. So that was a challenge, and so I had to find some resources and basically I assessed him on learning science related English words. Like—do you know what a ruler is? What’s that word in Spanish? What’s the word in English? Can you identify it? Can you write the English word if I showed you a ruler? That kind of stuff is what I’ve done. I had a couple of Arabic students who didn’t speak any English. That was a challenge. Again, it was kind of a vocabulary type of a thing. We don’t have an ELL person, so it’s kind of all on your own.

The Portfolio Because Dee has never taught physics, her portfolio submission involved the subject of chemistry. Her activity consisted of using LEGO blocks to simulate atoms in a chemical reaction. Dee felt this was a concrete method of presenting what is a very abstract concept to many ninth grade students. She mentioned the importance of utilizing something the student is familiar with to build a bridge toward unfamiliar material. Recall Redish discussed this tactic in Chapter 2. Dee commented, “I realized I need hands on activities for abstract concepts.” Like Gary, William, Dee felt the constructivist and context principle were important in her curriculum design decisions, but she also agreed with Kristi that the social learning principle was essential as well. In addition to her training at UWRF, Dee also specifically mentioned that her

department is planning to utilize a version of Bybee's 5E model for lesson planning that was discussed in Chapter 2. Dee does plan on finishing up her physics certification, and hopes to teach physics in the near future.

Closing Dee has spent the last nine years teaching various science courses. Initially, she thought she would be teaching physics in the district she currently works in. To date, that has not happened, but she is earning her physics certification and her Master of Science Education – Physics degree nonetheless. Like the other six case study participants, Dee also enjoyed the increased comfort that came with the collaborative, non-threatening nature of the River Falls program. Because she works primarily with ninth grade students, she has experienced some frustration with the level of the content presented by the River Falls program. She feels that her experience has certainly taught her valuable physics concepts to make her more knowledgeable, but she has not yet been able to find a way to bring what she has learned down to the level of a ninth grade physical science class. Dee is an example of a program participant with a different background from the majority of the other participants, and as such, her experiences and what she was able to take from the program differed as well. She valued the network of other science teachers she has now become a part of, and has been able to use ideas presented by them in the sharing sessions provided by the River Falls program, but unlike the other case study participants, she felt the River Falls program was lacking in the training of physics pedagogy.

Case Study Summary

Each of the case study participants brought a unique context and perspective through which to view the River Falls Summer Physics Training Program. The Five Principles introduced by Redish were evident in each case study, but the importance of and emphasis on each of the principles varied with each participant. In addition, certain features of the program were especially influential for particular case study participants. Some of these features appeared to be tied to the subject matter taught by the participant, that is, whether or not they taught physics as a part of their curriculum.

In terms of background, five of the seven cases had several years of physics teaching experience in their background at the time of this study. One of the remaining two was going to teach physics for the first time in the fall of 2010. The remaining participant has taught physical science but never physics.

Four of the seven cases have earned their Master of Science Education – Physics degree, with the other three intending to do so. Two of the three still working toward their degree are also working toward physics certification. The remaining five cases are currently physics certified.

Every case indicated that physics was not part of their initial certification. Three of the cases indicated they needed to add a physics certification to replace a retiring physics teacher. The other four cases indicated they needed to add a physics certification to fulfill the requirements of the job they were applying for. Consistent with the research on out of field physics teachers discussed in Chapter 2, all of these participants earned

their teaching certifications in something other than physics, and sought to add physics certification at a later date.

One of the first themes to emerge was the participants' perception of their level of preparedness to teach physics when they first began to do so. Four of the seven cases indicated they were not well prepared by their undergraduate physics experience to teach physics at the high school level. Of the remaining three, one case indicated he initially felt prepared until he entered the River Falls program and "saw what he had missed." The other two cases completed several years of the River Falls program before they taught their first physics course, so they never experienced teaching physics without it.

Comparing the undergraduate physics experience to the River Falls experience was another theme that emerged from the data. Every case participant noted differences between the two, although the degree of difference varied from case to case. Two of the cases actually attended River Falls as undergraduates, and as such, had the same professors for both their undergraduate and graduate level physics training. Despite being taught by essentially the same professors in the same classrooms, both of these case participants noted some key differences between the programs. Both cases mentioned that they felt more comfortable interacting with the professors in the graduate program than they did as undergraduates. They also felt the professors were more available to them in the graduate program. These are aspects of the social learning principle. Both cases also indicated they felt the lab portion of the graduate program was more intense and detailed, especially in terms of explaining the rationale for each step carried out in an experiment when compared to experiments done at the undergraduate level. Pam

mentioned the focus was more “teacher-specific” in the graduate program. She also stated that the graduate program was more collaborative and friendly in nature. Dee noted that she felt like she was treated more as a professional in the graduate program than she was as an undergraduate.

The other five cases reported that their undergraduate experience was far less personal than their graduate experience at River Falls. Several of them attended large state universities as undergraduates, and commented negatively on the experience of being in a lecture hall with “hundreds of students” and learning about physics. Nearly all of the cases reported that they felt their undergraduate physics experience was not at all focused on how to teach physics. Kristi referred to the undergraduate method of teaching physics as “shotgun blasting” material in an attempt to reach all of the majors. Steve commented on the fact that his undergraduate program never taught him to see how the various concepts in physics tied together. William stated that his undergraduate lab experience had no effect on him, while Gary struggled to even remember labs he had participated in as an undergraduate. These statements are related to the constructivist, context, and change principles.

When asked about the River Falls experience, every participant except Dee felt that this program focused much more on “teacher-specific” issues related to physics. Dee felt the material was presented at too high of a level for her students, and she did not feel that she was exposed to the physics pedagogy she was hoping for. It should be noted that Dee teaches ninth grade physical science, and to date, has not taught a physics course. Perhaps these are factors influencing her perception of the program. Jim, who teaches

physics exclusively to ninth grade students, and Pam, who will begin teaching physics for the first time to non-English speaking students also commented on the fact that they have had to simplify the content presented to them in the River Falls program.

Nearly every case member noted the smaller class sizes, increased availability of the professors, the sharing of ideas among active teachers, and the dorm housing creating a family atmosphere as very positive aspects of the River Falls program. These themes, consistent with the social learning principle, emerged many times throughout the case narratives. Nearly every case member also noted that the instructors were much more available to them, even to the point of interacting with them in social settings away from the classroom. They felt that being housed in the dorms and participating in evening study sessions after class created a sense of togetherness, that they were “all in this together” and several of the case participants commented on the positive nature of this situation.

Gary, Jim, and Pam were three case participants who were exposed to the Modeling curriculum discussed in detail in Chapter 2, while at River Falls. Each of them commented on the strengths of this approach in their interviews, and Gary uses it exclusively in his own classroom.

Several of the participants also commented positively on the sharing sessions that were a part of many of the courses taught at River Falls. Being able to see demonstrations conducted by high school teachers in a room full of high school teachers, and being able to discuss ideas and methods for using the demonstrations was viewed as

a valuable experience and specifically mentioned in both interviews and survey data.

Once again, there is evidence of the Social Learning Principle.

With respect to what River Falls participants were able to utilize from the program directly, there were many varying responses. However, several responses seemed to permeate many of the cases studied. For instance, nearly every case participant mentioned that the River Falls program increased their physics content knowledge, and that naturally carried over into the way they taught their students. Specifically, William, Gary, and Steve spoke to the fact that the program completely transformed the way they taught, the way they learned, and the way they approached their own students. This was especially significant in Gary's case, because he had already been teaching for fifteen years before he started the River Falls program. Despite his vast experience in the classroom, Gary indicated that River Falls had a profound effect on not only the way he taught, but also the way he viewed his students, and the way he viewed his own learning. William commented on how his experiences in the River Falls program affected far more than his classroom teaching. William honestly felt that the program positively affected the way he dealt with many aspects of his personal life outside of the classroom as well. These testimonies embrace all five of the Redish principles.

Every case participant noted the importance of making information as concrete, hands-on, and relevant as possible to the everyday lives of their students. This is consistent with the constructivist, context, and change principles discussed in Chapter 2. Participants such as Gary, who uses Modeling exclusively in his classroom, and Kristi,

who is trained in Vernier physics data-taking equipment usage, demonstrated using hands on activities on a daily basis to convey physics information to their students. Pam indicated she plans to incorporate Modeling into her physics program for English language learners, and Jim is experimenting with it in his ninth grade “Physics First” classroom. William said that the Modeling sounded like a good idea in theory, but admitted that he has an aversion to technology in the classroom. He completed the River Falls program before Modeling became a course taught in the program.

Most every participant commented on their ability to build conceptual bridges from material that their students are familiar with to more unfamiliar material. This is an example of the Constructivist and Change principles. Steve attributes his increased ability to do this to the fact that the River Falls program showed him how various physics concepts tie together. Most every other case participant mentioned in some way that leading students from familiar to unfamiliar material should occur in a series of incremental steps with what Pam called “scaffolding” along the way to ensure the students have a base upon which to build their conceptual understanding.

Every participant commented positively on the collaborative problem-solving atmosphere present in the River Falls program, and many of them indicated they have carried that atmosphere, consistent with the Social Learning Principle, over into their own classrooms. At some point in the interview process or the survey, each case participant placed a high value on their ability to learn physics in a non-threatening, collaborative setting where everyone in the room was working together toward a common goal. Though they did so to varying degrees, every case participant indicated that they use a

group format for instruction in their own teaching situations as well, and they all indicated that they felt it was an effective way for students to process information related to physics. Several participants also indicated that this method of instruction made it easier for them to identify misconceptions related to content possessed by their students. Steve mentioned that pencil and paper assessments do not always do a good job of unearthing a misconception. It is through the process of conversation and questioning and answering that these otherwise hidden problems often arise. Methods like these are consistent with the Change and Individuality principles.

To deal with the misconceptions and make an effort to create lasting conceptual change, Redish principle number three, every case participant indicated they believed in the use of multiple representations to present material. Though one participant tended to have her personal favorites, the remaining case participants agreed that using such things as graphs, equations, tables, sentences, paragraphs, and diagrams to convey information increased the chances that their students would be able to form a correct mental model of the physics material being presented.

Closely related to the use of multiple representations is the ability to translate from one representation to another. The literature indicated in Chapter 2 that most undergraduate physics programs take translation skills for granted, but he argued that translation is a skill that must be taught and should not be taken lightly. In this study, every case participant except Gary indicated that their students need help in learning how to translate from, for example, a graph to an equation, or from an equation to a sentence. Because Gary used the Modeling technique exclusively in his physics classroom,

translation skill building is a cornerstone of that curriculum. Nearly every participant stated that their undergraduate physics training did not teach translation skills at all. Several of them indicated that they got the impression that the ability to translate was something that each student came into the physics class with, or a skill they acquired on their own. Four of the seven participants indicated that the River Falls program did teach translation skills. In fact, Steve indicated that River Falls “stressed translation a ton.” Both Pam and Dee received their undergraduate training at River Falls, and while Dee mentioned that the graduate program placed more of an emphasis on translation, Pam never made that distinction.

With respect to teaching physics in the laboratory format, four of the seven participants specifically indicated they used aspects of the Modeling technique described in Chapter 2. Gary used Modeling exclusively, Jim used it with his upper level students, and Kristi used parts of the curriculum at times, though she admitted she has never been formally trained in Modeling. Pam indicated she liked the way it was presented to her, but at the time of this study, she had not actually taught physics. Dee and Steve indicated that they are shifting to a more open-ended inquiry-type lab format and trying to get away from the lock-step cookie cutter style experiments. Open-ended exercises are consistent with the constructivist and change principles. William never mentioned Modeling or inquiry, but did indicate that he tries not to focus too much on getting the “right answer” in the lab, but rather on accurately describing the process of gathering and interpreting the data.

Despite the fact that physics is often viewed as an upper level course, students with wide ranges of abilities and backgrounds still walk through the door. Because of this, most every participant had a method for accommodating the wide range of abilities possessed by their students. This is consistent with the Individuality Principle. Both William and Steve indicated they have a very approachable nature, and will work one-on-one with their students to ensure their individual needs are met. William indicated that he was “hard-pressed to fail a student” and would modify the curriculum to a great extent in order to avoid failure, but he admitted that those students did not learn as much under those circumstances. Jim relied on his teammate, a special education teacher, as he worked toward 100% inclusion in his ninth grade “Physics-First” curriculum. Unlike most physics teachers, Jim sees nearly every student in his district when they are freshmen. Kristi was in the process of changing her entire grading system at the time of this study. For her class, the grades are 20% formative, and 80% summative, but students can retry assessments. Punitive aspects of grading, such as taking points off for late work, have been removed from this new district-wide grading philosophy. Pam and Dee both indicated they focused more on vocabulary and word association with students that struggle with English. Pam will be teaching physics for the first time this fall in a course designed specifically for English Language Learners, and Dee has never actually taught physics. Gary did not mention accommodations specifically, but did indicate that his students often presented whiteboard findings of lab reports to the entire class, large group discussions coincided with the presentations, and students were permitted to make changes to their whiteboards before they were assessed. It was clear that methods of

assessment were varied across each case studied, but it was also clear that the methods used were part of a broader attempt to maximize success for their students. Several of the case participants indicated that one aspect of the River Falls assessment strategy, namely allowing students to choose five out of seven possible exam questions, has helped them ensure success for their students.

Despite the many positive things the case participants had to say about the River Falls Summer Physics Training Program, there were also some shortcomings. Five of the seven participants felt that many of the laboratory experiments they conducted in the River Falls program were done with equipment that would be too expensive to expect to find in a high school classroom. They expressed frustration with completing a valuable experiment in the program that they knew they would never be able to replicate with their own students because of the sheer expense of the equipment required. Dee, Pam, and Jim each felt that most of the course material was presented at a level far above what they needed for their own classrooms. In other words, they needed a context more appropriate for the needs of their students. They acknowledged that their own content knowledge grew as a result of their exposure to the material, but they expressed some frustration at the prospect of having to severely adapt the curriculum to meet the needs of their students. Dee also specifically expressed disappointment at what she perceived as a lack of presenting her with specific teaching techniques for her students. She mentioned that Modeling was the only course in the program where she felt she received pedagogical information in addition to just content. Dee had never actually taught high school physics, Pam will be teaching it for the first time this year, but it will be for students who

are English Language Learners, and Jim teaches a ninth grade “Physics First” curriculum that strives for 100% inclusion. Gary mentioned that the River Falls program never specifically addressed how to differentiate the material for various learning approaches, but did indicate he was able to incorporate this into his curriculum by using the Modeling technique. Steve and Kristi indicated they would have liked to see more technology-based learning. Kristi specifically mentioned Smart Boards, and Steve mentioned using more Internet related activities. It should be noted however that Kristi and Steve took the majority of their courses at River Falls in the late 1990’s. Both Kristi and Dee expressed frustration at the difficulties of being able to leave their families for weeks at a time and travel to River Falls for the training. Kristi specifically commented on wishing she had more time to be able to take more of the classes offered by the program.

Through the cross-case analysis, it became evident that all participants valued some aspects of the River Falls Summer Physics Training Program. Increased content knowledge, the ability to network with other physics teachers, and the warm, collaborative nature of the program seemed to resonate most strongly with the case participants. Though there was some disagreement on the level at which the content was presented to the participants, it seemed that participants who taught high school physics were, by and large, satisfied with the level of the material, while participants who worked with younger students, namely freshmen or middle school students, felt the material was too advanced. Consistent with Redish, nearly every case participant placed a high value on collaboration, using multiple representations, teaching translation skills, and making lessons relevant to the daily lives of their students. Though the River Falls program was

found wanting in several areas, it also scored high marks on several aforementioned areas deemed essential by Redish and others in Chapter 2 of this study.

A Summary and Comparison of the Survey and Case Study Findings

The seven case study participants were compared against the entire population of survey respondents, N=54, to check for similarities and differences among the responses given. In terms of demographics, some, but not all of the demographic data matched up between the case study participants and the survey population as a whole. The average years of experience was approximately twelve years for the entire population, and approximately fourteen years for the case studies. The case studies had nearly double the number of students receiving free or reduced lunch than the entire population. This could be due to the fact that two of the case participants taught in very small, rural schools, and one case participant taught in a very large, inner-city school, and in each of these schools, the percentage of students receiving free or reduced lunch was significantly above the overall average for the survey respondents of this study. The average size of the student population was slightly larger in the schools of the survey than in the schools of the case study participants. The average percentage of non-Caucasian students was higher in the schools of the case study participants, due in part to one of the participants teaching in an inner-city school with a non-Caucasian students making up approximately 80% of the population. The percentage of male and female students enrolled in the classes of the survey and case study participants was nearly equal, as was the percentage of students who had limited English proficiency. The case study participants' assessment of the

academic achievement of their own students relative to others in the state was similar to that by the survey participants. In terms of courses taken, the case study teachers had taken a higher number of UWRF courses on average, than the survey participants. This could be because 100% of the case study participants indicated they either had earned, or were hoping to earn, their Master of Science Education – Physics degree at some point, and this was not true of the entire population. The case study participants consisted mainly of people not yet physics certified, but intending to become certified, while the survey population as a whole consisted mainly of people who were already certified to teach physics, and who had already earned a master's degree. Though the program dated back to 1986, in both the case study group and among the survey respondents, the average date reported by respondents for taking their most recent physics course was 2006.

When comparing the results of Part II of the survey between the case study participants and the entire survey respondent population, it was found that, on average, the case study participants ranked items higher than the overall population. Part II of the survey focused on Redish's principles as discussed in Chapter 2.

Items 1-10 on the survey focused on teaching techniques geared toward the Constructivist Principle. In all but one survey item, item 9, the case study participants felt they experienced the various teaching techniques more often at River Falls than did the general survey population. However, for item 9, which pertained to placing students in a state of disequilibrium to create cognitive conflict, the case study teachers indicated they observed or experienced it to a lesser extent than did the general survey population.

In terms of the value the case study participants placed on constructivist practices, as represented by items 1-10 on the survey, the results were mixed. The case study participants seemed to value the practices slightly more than the general population, with the exception of item 6 regarding designing experiments specifically to uncover physics misconceptions, and item 9 which involved creating disequilibrium. With regard to how often the survey respondents used the constructivist techniques addressed in items 1-10 in their own classrooms, the results were mixed. For about half of the techniques, the case study participants indicated greater use than did the general population, and for the other half, they indicated less use than did the general population.

Items 11-13 addressed the Context Principle as discussed in Chapter 2. The case study participants ranked the frequency of occurrence at River Falls of practices related to this principle higher than the general survey population did. The case study participants also consistently placed a higher value on these practices than did the general population, and indicated they use these items in their classrooms to a greater extent than did the general survey population.

Items 2, 8,9, and 14-17 addressed the Change Principle as discussed in Chapter 2. With respect to the extent to which the case study participants felt they saw practices consistent with the Change Principle while in the River Falls program, they consistently assigned higher scores than did the survey participants except for item 9, which pertained to using disequilibrium, and for which their responses were slightly lower than for survey respondents as a whole. This pattern also held true for the value placed on practices associated with the Change Principle. In terms of using these practices in their

classrooms, the case study participants indicated they did this to a greater extent compared to other survey participants for all but two items. These were item 2, regarding teachers assessing students' prior knowledge at the start of a unit, and item 9, which involved using discrepant events to place students in a state of disequilibrium, whereby the student observes something that is in direct conflict with what they believe should happen. Several survey respondents indicated they considered this as tricking the student, and as such, they did not utilize this practice.

Items 18-22 addressed the Individuality Principle as discussed in Chapter 2. With respect to the frequency that these practices were present in the River Falls program, the case study participants' perspectives were mixed. They felt the practices pertaining to using varied teaching methods (item 18), and assessment strategies (item 19) to address student multiple intelligences, occurred more often than did the general survey population. However, they felt the practices pertaining to modifying lessons to accommodate diverse cultural backgrounds (item 20), and modifying lessons for English Language Learners (item 21) occurred less often than did the rest of the population. The case study and general survey populations were nearly indistinguishable regarding their perceptions of the degree to which River Falls instructors modified lessons for students with special needs, as described in item 22. The case study participants placed higher value than the general survey population did on all practices pertaining to the Individuality Principle except in the case of item 21, which addresses modifying lessons to accommodate students whose primary language is not English. For this item, the case study participants chose slightly lower ratings on average than the population as a whole.

When use of practices associated with the Individuality Principle in the classroom was considered, the case study population chose slightly higher ratings for items 18, 19, and 22, pertaining to using varied teaching methods to address multiple intelligences, using varied assessments to address multiple intelligences, and modifying lessons for students with special needs respectively. They chose slightly lower ratings than the overall population for items 20 and 21.

Items 19, and 23-27 addressed the Social Learning Principle as discussed in Chapter 2. In terms of the degree to which Social Learning Principle practices were present in the River Falls program, the case study group always assigned higher ratings than did the survey population as a whole. In addition, the case study group selected higher ratings on average than did the survey group regarding the value they placed on practices pertaining to the Social Learning Principle. Finally, the case study group also assigned higher scores for every item in the Social Learning category regarding the extent to which they used the practices described in their own classrooms. Upon examining the case narratives, it really comes as no surprise that these participants assigned relatively high scores in the Social Learning category. Every case study participant mentioned multiple times the importance, value, and prevalence in their own classrooms of practices such as creating a comfortable classroom atmosphere, collaboration rather than cutthroat competition, and group approaches to problem solving.

Ranking of the Five Principles With Respect to Research Questions 2-4

Upon examining the data obtained from the survey, the portfolio reflections, and the case study narratives, it was clear that, though each principle was mentioned, the order of preference for each principle varied depending on which sources of data were being analyzed as the following table will show.

Table 6. Principles ranked in order of occurrence, value, and use in the classroom.

Research Question	Data Source	Rank: 1= most 5=least
Occurrence in target program	Survey	1. Change 2. Context 3. Constructivist 4. Social Learning 5. Individuality
	Case Narrative	1. Social Learning 2. Change 3. Context 4. Constructivist 5. Individuality
	Portfolio	1. Context 2. Social Learning 3. Change' 4. Constructivist 5. Individuality
Value	Survey	1. Constructivist 2. Context 3. Social Learning 4. Change 5. Individuality
	Case Narrative	1. Social Learning 2. Change 3. Context 4. Constructivist 5. Individuality
	Portfolio	1. Constructivist 2. Context 3. Change

Table 6 Continued

		4. Social Learning 5. Individuality
Use in respondent classroom	Survey	1. Context 2. Social Learning 3. Constructivist 4. Change 5. Individuality
	Case Narrative	1. Social Learning 2. Context 3. Constructivist 4. Change 5. Individuality
	Portfolio	1. Context 2. Social Learning 3. Constructivist 4. Change 5. Individuality

In terms of occurrence in the River Falls Program, Context and Change ranked near the top for each form of data interpreted. Many of the survey respondents indicated that the increased exposure to the content in a variety of contexts did, in fact, aid them in their understanding of the material. Social Learning was mentioned many times as a critical component of the River Falls program during the case study interviews. The total immersion in a residential setting combined with many opportunities for reflection, sharing, and two-way communication with the instructors came across loud and clear as powerful agents for the participants' perceived success at deepening their understanding of physics. All three sources of data indicated that addressing the Individuality principle occurred less often than the other four. Perhaps this was because the program directors perceived the teachers as being a homogeneous group, or perhaps this is something directors of this program, as well as other programs, should pay more attention to.

In terms of value as perceived by program participants the rankings for the top four principles did alternate somewhat depending on the data being used. Yet these four principles ranked very close to one another throughout this process. Thus, a ranking of 1 in the table above should not be viewed as radically different than a ranking of 4. Once again, the lone exception was the Individuality principle, which finished a distant fifth in all three measurements.

In terms of use in the classroom, both Context and Social Learning were the top two in each type of data studied. It was clear that the teachers in this study used materials and situations relevant to the lives of their students whenever possible, and did so in an open, collaborative, non-threatening manner, and that these practices were positively influenced by their River Falls experiences. Constructivist, Change, and finally Individuality finished 3, 4, and 5 respectively for each type of data studied. The struggle teachers appeared to have with the Constructivist principle was the practice of frequently assessing prior knowledge of their students. The struggle with Change seemed to be tied to the idea that disequilibrium was a method of instruction viewed as cruel by the respondents. Individuality once again finished dead last, which is surprising given the demographically diverse student populations reported by some respondents as well as differences in ways of learning that exist in every student population. Regardless of the reason, the results of this study indicate that more attention should be paid to addressing the individual nature of the students we are teaching, as well as of the teachers we are preparing.

In the next chapter we will revisit the framework developed through the literature review, in response to Research Question 1, and its alignment with the results of this study. We will also examine how the data collection and analysis phases of the study inform Research Questions 2 - 4. Finally, we will explore the implications of this study for designers of physics programs for practicing teachers, the teachers themselves, and the physics education research community, and make recommendations based on the study's results to each of these audiences.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

Introduction

This chapter reports conclusions, implications, and recommendations regarding this study. The first section is a summary of the study that includes a review of the problem and the research questions as informed by the study. The next section presents implications and recommendations for designers of professional development, certification and graduate programs for physics teachers; current and prospective physics teachers seeking such programs; and those conducting research on physics teacher education.

Summary of the Study

The purpose of this study was twofold. First, I attempted to identify what components should be present in a research-based program specifically designed to develop the knowledge and practice of physics teachers (Research Question 1). Next, utilizing the University of Wisconsin – River Falls Summer Physics Training Program as the context, I attempted to answer three questions. First, I wanted to know what aspects of a program specifically designed to develop physics teachers' knowledge of physics content and pedagogical skills present in the target program in this study (Research Question 2). Next, I wanted to uncover what aspects of a program specifically designed to develop physics teachers' content knowledge and pedagogical skills are viewed as

important or useful by participants (Research Question 3). And finally, I sought to learn what aspects of a program specifically designed to further physics teachers' practices are used in the classrooms of participants (Research Question 4).

The literature review provided recommendations and a framework for effective support of the professional learning and practice of physics educators. The literature was used to develop a survey, interview questions, and portfolio design. Data was collected from surveys administered to 54 participants in the River Falls Summer Physics Training Program. In addition, case study data was collected in the form of interviews, and in some cases portfolios, provided by seven program participants.

Conclusions by Research Question

This section presents conclusions pertaining to each of the four research questions.

Research Question 1: What Components are Present in a Program Specifically Designed to Develop Physics Teachers' Understanding of Physics Content and Pedagogy?

The review of the literature provided the answer to this question. One of the first components deemed necessary by the physics education research community was that programs should stress a student-centered, rather than a teacher-centered curriculum. In other words, the student should be responsible for constructing his or her own mental models for physical phenomena, and the teacher should gently guide this process, rather than acting as a font of information. The work of Piaget, Karplus, and Bybee, was evident in the construction of the three exemplary physics teacher training programs

studied: Physics by Inquiry, Modeling, and The Physics Suite. In each of these programs, teachers are shown how to act as mentors and to guide students toward correct mental models by using techniques such as creating cognitive conflict and bridging. At the same time, these teachers are discouraged from “filling in the gaps” for their students in a way that weakens students’ own knowledge construction.

The work of long-time physicist and physics education researcher E.F. “Joe” Redish served as the organizing framework for answering Research Question 1, because it was found that existing physics education research evidence, as well as several model physics programs examined, were well aligned with this structure. Redish defined five principles that he felt were essential in the construction of any physics course aimed at creating lasting conceptual change in the minds of the students. The principles are: The Constructivist Principle, the Context Principle, the Change Principle, the Individuality Principle, and the Social Learning Principle.

Constructivism, according to Redish, involves the aforementioned strategy of making the student responsible for his or her own learning, and removing the teacher from the role of disseminator of knowledge.

The Context Principle reminds educators that students need relevant instruction that situates the phenomena being studied in familiar contexts, especially at the start, as students progress through Piaget’s stages of learning. This principle also reminds educators that we have many years of experience in which we have formed our own familiar contexts that our students do not necessarily possess.

The Change Principle is based on evidence that it is very difficult to learn something we don't almost already know. Here, the literature spoke to the stubbornness of common physics misconceptions, and the difficulty encountered by instructors as they try to remove them. It is here that the Principles start to overlap. The literature review showed that using a constructivist approach (defined in Chapter 2), while paying particular attention to the context in which the new material is presented, can increase the likelihood of breaking through stubborn physics misconceptions and thereby creating the opportunity for lasting conceptual change. Though the literature made it clear that this is by no means easy, it was deemed an essential component of an effective physics professional development, certification, or graduate education program.

The Individuality Principle is based on the assumption that each student has a unique approach to learning. Here, there was a dearth of information relating the topic of multiple intelligences, individuality, and physics education specifically. As such, literature relating student achievement in other subjects, namely English as a Second Language (ESL) courses, to attention being paid to applications of multiple intelligence theory was used instead. The results were exclusively qualitative in nature, so no definitive quantitative link can be discussed. Though the research in this area was weak, some teachers have reported success when considering multiple intelligences in their curricular design (for example, Bertrand, n.d. discussed in Chapter 2).

The fifth and final Redish Principle is the Social Learning Principle. The framework Redish chose for this principle was the work of Lev Vygotsky who assembled evidence that effective learning occurs most often through direct social interactions. As

such, the atmosphere of a classroom becomes significant as students move through Zones of Proximal Development (ZPD) as was discussed in Chapter 2. Several studies uncovered in the literature review provided evidence supporting the position that mental models take shape in a social setting, and can therefore be influenced by that setting. Practices such as small group discussions, laboratory exercises carried out with others, and other peer-to-peer interactions appear to assist students in creating lasting conceptual change.

Overall, the research uncovered in the literature review indicated that programs designed specifically to develop physics teachers' knowledge of physics content and associated pedagogies should look different than the typical undergraduate physics experience. The higher education community appears to be hearing this message, because more and more universities are identifying this as a need for their physics and/or education departments.

Research Question 2: What Aspects of a Program Specifically Designed to Develop Physics Teachers' Understanding of Physics Content and Pedagogy Were Present in the Target Program in This Study?

From the analysis of survey data gathered, presented in detail in Chapter 4, it can be concluded that according to students' perceptions, teaching practices related to the Constructivist Principle were present to a great extent in the target program, with the exception of regularly assessing students' prior knowledge when introducing a new topic. Similarly, the survey data analysis allows us to conclude that all aspects of the Context Principle were present regularly in the program studied. The same can be concluded with

respect to the Change Principle, which involves fostering lasting conceptual change, with the lone exception being the frequency with which the program instructors assessed prior knowledge at the introduction of a new topic. From the analysis of the survey data regarding the Individuality Principle it can be concluded that the program fell far short in the eyes of the survey respondents. Although program experiences sometimes addressed multiple intelligences, it was not with regularity. Analysis of participant survey results also indicated that the River Falls program seldom, if ever, addressed cultural differences, language barriers, or students with other special needs. That a large majority of the participants checked “Don’t Know” when responding to questions dealing with these issues can be interpreted to mean that respondents weren’t certain what constituted evidence of practices related to the Individuality Principle. Since the classes in the target program were quite homogeneous, it could stand to reason that cultural or language diversity were not factors for the River Falls professors to contend with as they presented their course material. Yet the data regarding the demographics of program participants’ own students provides evidence of diversity with respect to ethnicity, income, and academic performance. Therefore, we can conclude that it would be sensible for faculty to model strategies appropriate for their students’ students as they strive to better prepare the physics teachers at hand. It is possible that this omission arose because faculty had too little information available regarding their students’ pupils and teaching contexts. From the survey data analysis it can be concluded that the program adhered to the Social Learning Principle to a great degree. With the exception of not having a framework in place to ensure that all participants in a group project share responsibility for the group

product, respondents felt that Social Learning occurred with great regularity in the program studied.

Analysis of the case study data, presented in detail in Chapter 4, reinforces the conclusion that the target program adhered for the most part to the five principles discussed above. Case participants' responses showed that most did not feel adequately prepared for physics teaching prior to joining this program. In some instances the teachers recognized that their earlier preparation, for example, undergraduate physics courses, did not provide adequate preparation, and in other cases the deficiency of prior preparation was recognized only when the teacher began taking courses in the River Falls program and discovered "a whole other world" about how to truly teach physics. Case study data indicated that through the program teachers felt increased competence and readiness to teach physics, and they provided numerous illustrations. Consistent with the literature in Chapter 2, each of case study teachers began their careers thinking they would be teaching something else, and added a physics certification later on. Also consistent with Chapter 2, most of them felt very unprepared to adequately teach physics. Those who were more confident had the benefit of several years of exposure to the River Falls program before they began teaching their first physics course. It can therefore be concluded that a graduate level program such as the Summer Physics Training Program at River Falls does increase the confidence level of its teacher participants.

Analysis of the case study responses is also consistent with literature-based assertions in Chapter 2, that a physics program designed to develop high school physics teachers should look different than a traditional undergraduate or graduate physics

course, which are often designed for physics students in multiple options as well as non-physics majors. When asked if the River Falls Summer Physics Training Program looked at all different from what the case participants experienced in undergraduate physics courses, the answer was a resounding “yes,” and there was consistency in their observations and preferences. Nearly every case participant indicated the same key differences, including smaller class sizes, usually 24 students or less particularly among participants who attended large universities as undergraduates where physics classes often held hundreds of students in a large lecture hall. The participants also noted a different curricular approach and philosophy in the River Falls program. Undergraduate programs, as one participant put it, were akin to “shotgun blasting general information to hit all of the majors.” These same participants expressed a consistent preference for a program designed like that at River Falls that specifically tailored the information presented to the needs of a physics teacher. One participant elaborated on the influence of this tailoring of the curriculum by saying, “...the UWRF program was one that really taught me how all the concepts related to one another, and how I could help the students understand those relationships... It made me a lot more comfortable with what I was doing.” Clearly, a statement such as this strengthens the conclusion in this study of the need to customize the curriculum for teachers, in this instance by modeling the Change Principle.

Every participant also mentioned something about the classroom atmosphere and the total immersion in physics, as well as in a collegial community, that occurred in the River Falls program. The participants pointed out the extensive one-on-one time they

were able to have with their instructors, the fact that the instructors treated them as professionals, and the non-threatening, collaborative, almost “family” atmosphere that often occurred in the classroom. Several participants indicated that they observed the instructors treating all students, regardless of background knowledge or ability, with equal respect. Participants indicated the instructors in the River Falls program would spend just as much time with the physics expert as they would with someone coming in with little or no background on the subject, and they would tailor their answers to the ability level of the participant. The case studies also provided numerous statements about the positive influence on teachers’ learning of the immersion in physics that occurred for those who lived on campus. The teachers asserted that this was an excellent way to truly internalize the material being taught, and to form accurate working mental models of the topics being discussed. These statements provide further evidence of the Social Learning Principle being implemented in the River Falls program, and contribute to the conclusion that this principle contributes to the value and effectiveness of a physics teacher education program from the viewpoint of participants.

The participants consistently noted the positive impact of the sharing sessions held at the conclusion of each course in the River Falls program. Getting to see demonstrations set up and performed by high school physics teachers and spending the day discussing what worked and what did not was viewed as a very worthwhile experience. This was especially true of participants who were relatively new to the field of physics, or to physics teaching. The networks that were formed as a direct result of the sharing sessions were also mentioned as strengths of the program. These sharing sessions

provided exposure to each of the five Redish principles. The teachers' consistently strong support for these sessions leads to the conclusion in this study that they should be considered as central design elements, not as advisable yet peripheral, in programs for physics teachers.

With respect to the laboratory setting, most of the participants felt the labs in the River Falls program were more open-ended, and less cookbook, than the physics labs they did as undergraduates. They indicated that the River Falls lab curriculum, especially the Modeling curriculum, was much more applicable to what a high school physics teacher needed because of the emphasis placed on multiple representations of data, teaching the skills to translate between these forms of data, and allowing the participant to express their ideas in a variety of ways. Readers will recall from Chapter 2 that Modeling was chosen as one of the three exemplary programs because of its strong adherence to the five principles. Based on the consistent support for Modeling expressed by participants, and their statements about the relevance of this approach to promote learning in their own classrooms, a conclusion of this study is that laboratory experiences with similar features should be included in programs for physics teachers.

Two of the participants also indicated they were not as impressed with the material presented in the River Falls program. They felt the material was "too far above" the ability levels of their students. These participants indicated they would have liked to see things brought down to a level more appropriate for their students. It should be noted however, that these participants worked primarily with ninth grade students, and students who struggle with the English language. It certainly is possible that the River Falls

program did not take teachers in situations such as these into account when they designed their physics curriculum for high school teachers. Perhaps River Falls could take a closer look at Redish's Individuality principle as they make plans for future aspects of their program. A conclusion of this study is that programs for physics teachers should gather information about the contexts in which the teacher participants will apply what they learn, including key characteristics of their science programs and students, and take a closer look at Redish's Individuality Principle as it applies in today's diverse classrooms as they revise their curricula.

It was clear from the survey responses and the case study data that participants saw consistent evidence of Redish's five principles while participating in the River Falls program. Although each individual took something different out of his or her experience, the benefits they reported – whether creating a comfortable and collegial atmosphere for their own students, or introducing their students to the art and science of separating relevant information from distractions – often appeared to stem directly from the application of one or more of these principles. Based on these findings, it can be concluded that Redish's research-supported framework contributed substantially to the benefits that participants reported.

Research Question 3: What Aspects of a Program
Specifically Designed to Develop Teachers' Understanding
of Physics Content and Pedagogy as Important and/or
Useful by the Participants in the Target Program of This Study?

The survey and case study data attempted to ascertain the value that participants placed on various aspects of the Redish principles. Nearly every item in the strand of the

survey addressing value received an average score of 4 or better on a 5-point scale. Once again, lower ratings were assigned to the use of disequilibrium to promote conceptual change, and modifying lessons for English language learners and other students from diverse cultures. It is noteworthy that the survey data gathered for this study showed that some of the teachers worked with diverse populations. These teachers did place a higher value on teaching physics with an emphasis on language, culture, and diverse ways of knowing.

In terms of what the participants did value, both the survey and case study data provided similar evidence. Nearly every participant stated that they liked to use something interesting or attention grabbing to hook their students into discussion of new material, and many stated that they liked to use inquiry-based methods of instruction at the start of a unit to get their students gathering data and searching for patterns and relationships as quickly as possible. These valued methods are consistent with the Constructivist Principle. Every participant indicated that they tried as much as possible to make the information relevant to the everyday lives of their students, which is consistent with the Context Principle. The participants also emphasized the importance of guiding students incrementally through unfamiliar material, and using a familiar concept as an anchor to bridge to unfamiliar topics. This was consistent with our definition of the Change Principle. Participants also indicated the importance of repeated exposure to difficult or unfamiliar material, and specific ways to present challenging material differently.

Redish mentioned the use of multiple representations as a method of accomplishing initial and lasting conceptual change, the goal of the Change Principle. The case participants in this study agreed with Redish, stating that use of multiple representations was effective for them as learners, and as they worked with their own students. Like the authors whose work was reviewed in Chapter 2, the participants agreed that representing data in more than one way – for example, using data tables, diagrams, graphs, equations, sentences, paragraphs, hands-on experiments, pictures, and simulations – increased the chances that their students would begin to form correct mental models for the phenomena being studied. This practice actually has its roots in several of Redish’s principles, namely, Context, Change, and Individuality, and permeates many fields in addition to just physics.

Closely related to the use of multiple representations is the ability to translate from one representation to another. In Chapter 2 it was noted that Redish and others lament that translation is often taken for granted or “glossed over” in undergraduate physics courses, a point that case study participants in this study agreed with emphatically. Translation relates to both the Context and Change principles. Every case participant in indicated that translation skills did not come naturally to their students, that teaching these skills is essential to increasing student understanding of physics, that they had experienced this first-hand as physics learners at UWRF but not in undergraduate programs elsewhere, and that the UWRF experience had greatly influenced their position on this topic. This study concludes that students in the target program highly value the

teaching of translation skills, a position that is consistent with existing physics education research reviewed in Chapter 2.

Closely tied to what participants valued, were the practices they chose to use in their classrooms. This is the topic of the fourth and final research question for this study.

**Research Question 4: What Aspects of a Program
Specifically Designed to Develop Teachers' Knowledge of
Physics Content and Pedagogy are Incorporated in the Classroom
Practice of Participants in the Target Program Being Studied?**

Much of this question has been covered in the discussion for Research Question 3 above. It stands to reason that if a teacher values a particular technique or practice that he will then bring that technique or practice into his classroom to the greatest extent possible.

Survey responses indicated that most items related to the Constructivist Principle were used in the classrooms of the respondents. A notable exception once again, was item 9, which asked if the participants used disequilibrium to facilitate cognitive conflict and ultimately conceptual change. Participants did not feel this happened often at River Falls, did not place a high value on this technique, and did not use it to a high degree in their classrooms. Several participants argued that disequilibrium equated to purposely tricking or further confusing the student, and they felt this was not an effective method for providing physics instruction. The participants pointed out that when a student is attempting to learn something new, they are often in a very frightened and vulnerable state, and as such, furthering their confusion and uncertainty, these teachers did not feel comfortable exacerbating these feelings. However, it should be noted that physics

education researchers point out that creating disequilibrium can be an effective strategy for targeting physics misconceptions provided the classroom atmosphere is such that a strong support network exists among the students, and the instructors take great care to gently guide the vulnerable student in the right direction. Under circumstances such as these, students are not as afraid of looking silly in front of their classmates, and disequilibrium can, in fact, provide positive results for the learner. The case study interviews and portfolios also provided consistent evidence of application of many aspects of the Constructivist Principle by participants. Thus a conclusion of this study is that participants in the UWRF program used many aspects of the Constructivist Principle in their classrooms. The study design does not allow us to say with certainty to what degree the program influenced this choice, but case study participants indicated the influence was substantial.

Survey respondents indicated that they applied the Context principle in their classrooms, choosing ratings of 4 on a 5-point scale. Analysis of the case study interviews and portfolios also point to the conclusion that participants in the target program use many strategies associated with the Context Principle in their classrooms.

Regarding the Change principle, the data was mixed. Respondents indicated a high degree of use of the practices described in about half of the items, but not for the other half. Respondents reported using multiple representations to convey information, and teaching students to translate across representations, and these examples of applying the Change Principle were also seen in case study interviews and portfolios. As in their responses regarding the practices they valued, participants assigned relatively low ratings

to items involving disequilibrium, assessing prior knowledge, and introducing concepts multiple times. Paradoxically, survey respondents indicated that assessing prior knowledge was not a frequent practice at River Falls, that they placed a high value on this practice, yet did not utilize it often in their classrooms. Perhaps this is additional evidence that teachers will teach as they have been taught, even if their instincts tell them otherwise. The interview and portfolio results were also mixed with respect to implementation of strategies associated with the Change Principle in case study participants' classrooms. Thus this study concludes that UWRF participants implement Change Principle strategies selectively.

Individuality Principle items received relatively high scores when they inquired about the degree to which respondents adapted instruction for multiple intelligences, and lower scores with respect to differentiating instruction for special needs students, English language learners, and students coming from diverse cultures. In the case study interviews, it was found that teachers who worked with a more diverse population tended to use practices related to diversity more than teachers in more homogeneous districts. The conclusion is inescapable that teachers in the target program are not applying the Individuality Principle to the same degree as the other principles. This is not surprising in that participants tended to value these practices less than those relating to other principles, and reported that they were given less emphasis in the UWRF curriculum.

Practices related to the Social Learning principle were reportedly used with regularity in the classrooms of survey respondents and case study teachers. Consistent with the literature from Chapter 2, the collaborative, non-threatening learning

environment that relies on group approaches to problem solving and the sharing of ideas, resonated with respondents. They reported that River Falls created this type of learning environment, and that they as secondary teachers valued and applied it their own teaching.

Budgets came up in discussions with case study participants about offering laboratory experiences for students. Several of the case participants worked in rural districts where lack of funding for equipment was a serious issue. We must conclude from the teachers' statements that financial constraints influence their ability to apply highly valued aspects of the Redish Principles in their classrooms.

The case study participants in this study all taught in public school settings where they encountered students with widely varying skill sets and abilities. As such, it was expected that these teachers would accommodate students with special needs. The Individuality Principle states that each student has a unique learning style, and that teachers should find out what that style is and adapt accordingly. Case study participants reported a variety of accommodations including taking the time to get to know each individual student; easing grading policies so that hard-working students could be successful; emphasizing techniques for learning vocabulary related to science subject matter for English language learners; and allowing students to complete alternate projects to demonstrate understanding. One instructor with nearly 100% special needs students in his freshman physics class enlisted the help of the special education department. He team-taught his course with a special education teacher, and they utilized each other's strengths toward inclusion of all students. A conclusion of this study is that the case

participants were paying attention to both instructional accommodations and modifying assessments as they designed and implemented their physics curricula.

Despite the varying degree of use of specific Redish principles among the case study participants, the overall feeling I had was that the teachers genuinely cared about their students and wanted them to succeed. The teachers appeared to be very open to exploring alternate methods of instructing and assessing students to promote that success. I did not sense any rigidity or unwillingness to explore other possibilities during the case study interviews. Budgets were a serious concern in several of the districts, but the teachers studied in these financially strapped districts were upbeat about the future, and working tirelessly toward providing their students the best education they could within the bounds of available resources. This was profoundly encouraging.

Implications and Recommendations

In the next sections we will explore implications and recommendations based on this study for those designing and implementing physics education programs for practicing teachers, for teachers of physics themselves, and for researchers whose aim is to better understand program designs that enhance practicing teachers' knowledge of physics content and pedagogy.

Implications and Recommendations for Designers of Physics Education Programs for Practicing Teachers

The findings and conclusions from this study provide support for the claims made by the physics education research community that programs designed to develop physics

teachers should look different than traditional physics programs. Teachers of physics need a different knowledge and skill set than people going into other professions. What should such programs look like? According to my research, an increased focus on how physics material ties together should be provided in a program designed for physics teachers. Providing teachers with experience using multiple representations for data and fostering the skills required to translate between these representations should be viewed as central in such programs. Prospective teachers should be trained how to conduct open-ended, inquiry-based laboratory experiments within their classrooms. Exemplary programs such as Modeling, Physics by Inquiry, and the Physics Suite that incorporate multiple representations, translation skills, and specifically target common physics misconceptions should be consulted or utilized during program design. Care should be taken to create a non-threatening collaborative atmosphere where prospective teachers feel encouraged to discuss their ideas and justify their points of view. The focus should be on group efforts to attain physics knowledge rather than on cutthroat competition. Misconceptions should be pre-assessed, and brought to the forefront whenever possible, and the students in the program should be given ample opportunity to come face to face with these misconceptions and construct their own revised mental models of the phenomena being observed based on their own direct experience, not by virtue of authority. It can be argued that the only way an instructor can address a misconception contained within the prior knowledge of a student is to assess that prior knowledge in some fashion very early in the course. Only when we know where our students are, can we help them get where we want them to be. Pre-tests, pre course surveys, or an online

discussion format where students can share their prior knowledge about various topics that will be covered in the course are but a few methods that could be incorporated into a successful physics teacher training program with relative ease. The instructor could use the information gathered in this fashion to tailor the curriculum to specifically address and ultimately remedy problems that might otherwise go unnoticed in a typical physics course.

The research clearly showed that most physics teachers began their teaching career in a field other than physics. Students aspiring to become physics teachers come from a wide variety of disciplines, and as such, designers of programs aimed at creating competent physics teachers need to take this variety of backgrounds into account. Perhaps some sort of pre-assessment to determine the level of prior knowledge possessed by the incoming student could be used as a template for the program to tailor a program for him or her. This study reinforced the notion that students in physics teacher professional development programs are anything but a homogeneous group of people, and designers of programs for physics teachers must take that into account.

Because these newly minted physics teachers will be taking what they acquire in their training programs into a wide variety of secondary school settings, it stands to reason that program designers need to learn about the diverse settings where their graduates will work. For example, one of the case participants in this study taught physics in an inner-city school where over 50% of her students are English Language Learners. Clearly, her needs are different than someone working in a suburban school with a more homogeneous student population.

Case study teachers provided numerous examples of aspects of the River Falls program they were able to incorporate into their own instruction. Programs for physics teachers need to intentionally build in mechanisms to show participants who find something potentially useful how to implement that idea in their own classroom. The River Falls program modeled what such intentionality might look like. For example, the program's philosophy included providing participants with laboratory equipment, as well as training in how to use it in their classrooms. This is one example of many small gestures that allowed participants to recreate the instruction modeled by the program in their own schools. The participants not only learned how to use the piece of equipment, but they can then take that piece of equipment back to their classroom and utilize it with their students. It is practices such as this that foster transfer, empower teachers, and enhance the learning experience for participants' students as well.

This study provided evidence of the importance of providing the financial support necessary, for example, through stipends and other forms of grant funding, so that teachers will have the means to further their physics education. It is no secret that teachers do not earn what many in the private sector earn. As such, finding creative methods of providing training in physics education to teachers while removing the barrier of cost could make earning physics certification or a graduate degree more of a reality to many more prospective teachers. As we learned in Chapter 2, as well as the case studies, very few educators enter the teaching profession are certified in physics. If this country is serious about wanting more teachers certified, qualified, and competent in fields such

as physics, then we need to address the financial aspects of assisting teachers to reach these goals.

The findings and conclusions from this study supported the importance of giving teachers opportunities for immersion in the subject matter. In the case of River Falls this was accomplished through a residential program. This was reported by case study participants to have a positive impact on their physics learning, the strong appreciation they developed for the learning experience as a whole, and what they carried over into their own classrooms. Most case study participants took up residence in the dormitories at River Falls. Yet today residential programs are difficult to maintain because many teachers are either unwilling or unable to commit to two or three weeks in the summer to complete the coursework. Perhaps creative ways to attract these teachers either financially or with other rewards could allow these programs to continue. Another option could be the use of distance learning. Perhaps sharing sessions or study groups could be carried out in an online format using current technology such as chat or videoconferencing. The laboratory experience could pose some challenges in this format, but if each student had the equipment in his or her own classroom, perhaps some experiments could be carried out independently, and the subsequent discussion could take place online. With ever-improving technology, this could certainly be an area of further study.

This study found evidence that laboratory equipment provided to teachers in the River Falls program made a critical difference for some, providing them with the wherewithal to offer a wider range of laboratory experiences to their students. Financial

hardship is a reality of many districts throughout the country as well. As such, access to the laboratory equipment so essential to creating the hands-in inquiry based classroom experiences consistent with the Constructivist principle is but a distant dream for many competent teachers. Physics teacher education programs should seek out methods to assist the participants in acquiring this much needed equipment. All of the preparation and dedication in the world will not suffice if the teacher is forced because of inadequate laboratory equipment to minimize the role of student inquiries.

It should also be pointed out that courses taught in the spirit of Modeling, Physics by Inquiry, or the Physics Suite take a great deal more time to address content than a more traditional lecture-based course. Hands-on experiences followed by multiple representations and time for translation, reflection, and integration of new knowledge with pre-existing knowledge takes a great deal of time. As a result, physics courses taught in this fashion tend to focus on a narrow band of topics, often Mechanics. In the traditional lecture format, Mechanics is but one chapter placed alongside Thermodynamics, Wave Physics, Electricity and Magnetism, Optics, and Modern Physics, to name a few. This is a double-edged sword. On the one hand, research clearly shows that using the methods described in Chapter 2 do, in many cases, lead to lasting conceptual change, more so than the traditional lecture approach to instruction. However, this increase in depth of knowledge comes at the expense of the breadth of physics topics covered within the course. There is no easy answer to this question. Perhaps offering more than one physics course in a high school could allow the instructor to maintain the depth of a Modeling curriculum, while allowing more time to cover

additional areas of physics that the exemplary programs in Chapter 2 do not allow for in a one-year course. This is not an easy matter to address.

Clearly these are major obstacles to consider. However, I believe that in order to remain competitive in fields such as science, technology, and mathematics, this country needs to find creative ways to recruit teachers into these fields, retain and enhance the training of the teachers we already have, and provide them with the equipment they need to do their jobs effectively.

Implications and Recommendations for Physics Teachers

For teachers of physics who have spent their careers teaching out of field, which is the case for the majority of physics teachers practicing today, the news that physics education is undergoing a transformation should be encouraging. Program designers are realizing the unique needs of physics teachers, and as such, programs such as the River Falls program are being created to address these needs. For teachers who have been trained as physics teachers, the fact that new programs utilizing the most recent discoveries in physics education and cognitive theory are being developed should also be encouraging. The fact that the country realizes that there is a shortage of certified, qualified, competent physics teachers available, particularly in impoverished and remote (rural or urban) school districts also creates a sense of hope that something will be done to address this growing problem. This study provided evidence of the qualities that practicing teachers value in a physics education program. This is important, since not all programs for practicing science teachers are created equal. Based on the survey and case

study responses presented here, it can be said that current or aspiring teachers of physics should seek out and support professional development, certification and graduate programs that include elements like the following. The program should recognize and embrace the wide variety of backgrounds possessed by the participants. The program should strive to increase the physics content knowledge of the participants, regardless of the level they come in with. The program should utilize a variety of teaching methods readily applicable to the classrooms of the participants. The program should encourage networking, sharing, and collaboration among participants. And finally, the program should be taught in a comfortable, non-threatening, though still rigorous fashion.

Implications and Recommendations for the Physics Education Research Community

As physics education research moves forward, there are several things we can look for. When examining a program such as Physics by Inquiry, Modeling, The Physics Suite, or the River Falls program, data gathered in the form of surveys, case study interviews, and portfolio submissions is useful, but it is no substitute for direct observation, or even direct participation. Becoming part of the classroom community, either as a traditional observer, or a participant observer, could certainly enhance the ability of the researcher to get a clearer picture of what exactly the program entails. Being able to meet with participants face to face, while they are actively being exposed to the material presented in the program could potentially result in otherwise unobtainable information being generated.

Likewise, when investigating actual utilization of program features within the classrooms of participants, direct classroom observation would complement other forms of data collection and enhance triangulation across sources to gauge the credibility of the themes and storylines identified.

Another avenue of exploration involves getting to know the participants as they enter the program in order to best meet their needs. This study reinforced the idea that the teachers participating in these programs are a very diverse group of people, and work in diverse contexts. There is a need for research that explores new methods to better address the individuality of the participants with respect to their background knowledge, and unique student demographics and school environments.

Exploring creative ways to utilize technology and facilitate distance learning for physics teachers is emerging as an area of future study. For teachers in remote locations, or teachers who simply cannot commit to a residency program for other reasons, utilizing various Internet technologies to create virtual classrooms, online sharing sessions, and networking and support groups could open the door for more teachers who are thinking about earning physics certification or a graduate degree, but cannot make it a reality.

This list is certainly not exhaustive, but it does provide some directions for physics education researchers to travel as we continue seeking ways to provide the most effective training possible for teachers, so they can provide the best education possible for our students.

Author's Closing Reflections

Like so many others, I too began teaching physics as an out of field teacher. My background was in chemistry and general science, and all that I had were ten credits of undergraduate physics when I was thrust into the role of physics teacher rather unexpectedly. Immediately upon assuming that role, I realized I was in deep trouble in terms of trying to effectively teach the subject. My lectures were a disjointed conglomeration of isolated facts and figures with no plan whatsoever of how to tie them together. In other words, I was using a dead leaves model. I was teaching as I myself had been taught several years before as an undergraduate. It was at that point that I enrolled in the River Falls program, which has served as the context for this study. Almost immediately, I sensed a tremendous difference in the focus of this program. It became evident as I conducted this study that my perceptions of the program were not entirely unique. It also became evident that other researchers examining other programs had arrived at a similar conclusion to those generated here. Physics programs designed for educators should look different than physics programs designed for other majors, and this study attempted to ascertain exactly what the differences should be. By examining successful research-based programs, and gathering data from program participants, this study helped to paint a clearer picture of what aspiring physics teachers need, how physics teacher training programs should be constructed in order to meet those needs, and how much of what is being taught in these programs is being carried over into secondary physics classes. It is my hope that this study will allow future program designers the

opportunity to address some of the gaps observed in existing programs, so that the next generation of programs will be even stronger than the current one.

It is my hope that as research on best practices for teaching secondary physics continues, I can continue to be a part of that process.

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APPENDICES

APPENDIX A

UNIVERSITY OF WISCONSIN—RIVER FALLS SUMMER
PHYSICS PROGRAM PARTICIPANT INFORMED CONSENT
FOR PARTICIPATION IN RESEARCH FORM

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY

Project: Investigating best practices for teaching high school physics.

You are being asked to participate in a research study to investigate the best practices for the teaching of high school physics. The Summer Physics Program at the University of Wisconsin—River Falls will serve as the context for this study. This study will help physics educators and universities with programs designed to develop and certify educators in the field of physics identify successful components of programs involved in the certification process.

You have been chosen because of your assignment to teach either physics at the high school level, or physical science at the middle/high school level.

If you agree to participate, I will collect data from you in the following manner:

1. I will send out an initial questionnaire to you. This will involve answering open-ended questions related to your opinion about several aspects of the summer physics program for teachers at UW-River Falls.

Based on the responses of the participants involved in the study, a survey may be sent to you at a future date, wherein you will rank various aspects of the program on a Likert-Scale (for example, 1= not effective – 5 = extremely effective).

You may be asked to participate in a telephone interview. During this interview, you will be asked about what you observed while participating in the River Falls program, what value you placed on various aspects of the program, and what you have decided/not decided to utilize from the program into your classroom.

You will also be asked to submit a portfolio entry showing evidence of your teaching practice.

We want you to know that:

1. Your participation is confidential and voluntary.
2. You may choose not to participate or to withdraw your consent at any time without penalty.
3. You will receive a stipend for your participation. If you choose to withdraw from the study, you will receive compensation for the time that you have contributed to the project.

4. Participating in this study may also have some general benefits in that you will be contributing to the improvement of teacher education and student learning.
5. The risks for participating in this study are minimal. This may include risks such as feeling uncomfortable talking about your teaching beliefs, or sharing negative opinions you may have about the UW-River Falls program.
6. Your decision to participate/not to participate in this study will have no effect on your professional standing within your school district, nor your ability to continue participating in the summer physics program at UW-River Falls.
7. All data collected from you and personal information will be kept confidential and secured in locked offices or in password protected computers. No one outside the principal investigator and approved research staff will have access to your information. Your privacy will be protected to the maximum extent allowable by law.
8. In research papers or other public presentations resulting from this study, your name will not be used and any identifying characteristics or personal information that could be used to identify you will be deleted or masked. It is highly unlikely that anyone would be able to identify you from any published report. Your privacy will be protected to the maximum extent allowable by law.
9. If you have any questions or concerns regarding your participation in this study you can contact me at:

Randall G. Ketola, 441 S. Larson St., Richland Center, WI 53581 (608)-647-9818

10. If you have questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – Institutional Review Board Chair, 960 Technology Blvd., Room 127, Bozeman, MT 59717. For information and assistance, call 406-994-6783.

Your signature below indicates your voluntary agreement to participate in this study.

=====

Participant's Signature _____ Date _____

Researcher's Signature _____ Date _____

APPENDIX B

UWRF-SUMMER PHYSICS PROGRAM SURVEY INVITATION

Dear Fellow Physics Teachers,

My name is Randy Ketola, and I am reaching out to each of you to ask a favor. I completed the UWRF MSE-Physics program in 2000, and continue to teach high school physics. To further my interest in physics education, I am also enrolled in a doctoral program. For my dissertation research, I am studying the types of professional development and coursework that physics teachers find most valuable. Part of my study takes place in the context of the UWRF program, and that's why I am contacting you.

With permission from the UWRF program, I am asking you and other program participants and graduates to complete an online survey that will help me get a clearer picture of your experiences in the UWRF program, and the features that were most relevant to your personal growth and your work as a physics teacher. The results will be of interest not only to the UWRF faculty, but also to physics teachers and "teachers of teachers" everywhere. Your expertise and feedback are greatly appreciated.

Completion of the survey should not take longer than 30 minutes, and your responses will remain strictly confidential. Responses will not be tied to specific responders.

At the conclusion of the survey, I ask for permission to contact you via email in the event I need more information regarding your responses or teaching situation. Providing your contact information does not automatically mean I will be contacting you, it simply means you are allowing me that option.

Thank you on behalf the physics education research community, the UWRF summer physics teacher training program, and the countless high school physics students we serve.

To access the survey, simply click on this link:
<https://www.surveymonkey.com/s/T2JVRJP>

And simply exit when you are done.

Have a great spring semester,

Sincerely,

Randy Ketola

Richland Center High School

ketr@richland.k12.wi.us

rgketola@hotmail.com

608-647-9818

APPENDIX C

UWRF-SUMMER PHYSICS PROGRAM SURVEY

UW- River Falls Summer Physics Program Survey

1. Background Information

Dear Summer Physics Participant, thank you for taking the time to complete this survey.

The first 12 questions of this survey ask you to tell us a little about your teaching experience, your level of experience with the UW-River Falls summer physics program, and the characteristics of the district in which you teach.

After each item, there is a space for you to comment on the choices you have made in order to add clarification as you deem necessary. Please note that comments are not required, but if you feel the need to elaborate on one of the questions, you are encouraged to do so.

* 1. How many years have you taught?

How many years have you taught?

☐ This is my first year
 ☐ 2-5
 ☐ 6-10
 ☐ 11-15
 ☐ 16-20
 ☐ 21+

Additional comments

* 2. What subjects, and at what grade levels have you taught/are you currently teaching?

* 3. What percentage of the students in your building are eligible for free or reduced lunch?

Percentage of students eligible for free or reduced lunch

☐ 0-10%
 ☐ 11-20%
 ☐ 21-30%
 ☐ 31-40%
 ☐ 41-50%
 ☐ over 50%

Additional comments as necessary

UW- River Falls Summer Physics Program Survey

*** 4. How would you describe the school building in which you teach in terms of the size of the student population?**

less than 200 200-400 401-600 601-800 801-1000 1000-1500 1501-2000 over 2000

Size of student population ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Other (please specify)

*** 5. What percentage of the students in your classes are NOT Caucasian?**

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

Percentage of non-Caucasian students ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Please feel free to add additional comments

*** 6. What is the approximate percentage of male and female students in the courses you teach?**

Percentage of males

Percentage of females

*** 7. What percentage of the students in your classes have limited English proficiency?**

0-10% 11-20% 21-30% 31-40% 41-50% over 50%

Percentage of students with limited English proficiency ☐ ☐ ☐ ☐ ☐ ☐

Other (please specify)

UW- River Falls Summer Physics Program Survey

*** 8. How would you compare the achievement level of most of your students to those of students from similar classes in your state?**

	Far below most other students.				About the same as most other students.				Far above most other students.
Comparison of student achievement levels.	☐	☐	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

*** 9. Please indicate which of the following UW-River Falls summer physics certification courses you have taken (Note: Please check either TAKEN or NOT TAKEN for each course listed).**

	taken	not taken
Mechanics (core course)	☐	☐
Electricity & Magnetism (core course)	☐	☐
Modern Physics (core course)	☐	☐
Astronomy	☐	☐
Astrophysics	☐	☐
Acoustics	☐	☐
Optics	☐	☐
Laser Physics	☐	☐
Thermodynamics	☐	☐
Use of Physics Technology/Equipment in the Classroom	☐	☐
Modeling	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

* 10. What were your reasons for entering this program (check all that apply)?

- ☐ Taking courses for general interest
- ☐ Taking courses to maintain current state teaching licensure
- ☐ Taking courses to become a licensed physics teacher
- ☐ Taking courses to earn Master of Science Education-Physics degree

Other (please specify)

* 11. What is your current status in terms of physics certification?

- ☐ Not physics certified, do not intend to become certified.
- ☐ Not physics certified, intend to become certified through UWRF program.
- ☐ Physics certified, not seeking MSE degree.
- ☐ Physics certified, seeking MSE degree.
- ☐ MSE-Physics, and physics certified.

Additional comments

* 12. When did you take your most recent UW-River Falls summer physics course?

	pre-2001	2001	2002	2003	2004	2005	2006	2007	2008	2009
Year of most recent UW-River Falls course completed.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

2. Summer physics experiences

The following 27 questions relate specifically to teaching practices and ask you to address them in three ways. First, you will be asked to what extent this particular practice was present in your experience as part of the UW-River Falls program. Second, you will be asked to what extent you value this particular practice as essential to what you perceive to be effective teaching. Third, you will be asked to inform us as to what extent you utilize this particular practice in your own classroom.

The comment spaces are provided if you wish to elaborate on a particular question.

UW- River Falls Summer Physics Program Survey

The final two questions ask you to provide voluntary contact information if you are willing to participate further in the study, or serve as a possible case study participant.

*** 1. When a new topic is introduced, the teacher provides some form of engagement to arouse the curiosity of the student such as a demonstration, a thought provoking question, or a classroom discussion.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls.	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson.	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom.	☐	☐	☐	☐	☐	☐

*** 2. When a new topic is introduced, the teacher assesses students' prior knowledge to modify instruction.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Add additional comments if desired.

UW- River Falls Summer Physics Program Survey

*** 3. Students explore concepts by gathering data and searching for patterns or relationships.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments if necessary

*** 4. The students are encouraged to explain observations in their own words verbally, in writing or by other means.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments if necessary

UW- River Falls Summer Physics Program Survey

*** 5. The students are encouraged to justify or defend their points of view verbally, in writing or by other means.**

[illegible]

Additional comments if necessary

--

*** 6. Observations and experiments are often designed specifically to address common physics misconceptions. For example, believing a heavier object will fall faster than a lighter object.**

[illegible]

Additional comments

[illegible]

*** 7. The teacher acts as a facilitator, guiding students toward forming their own mental models of the observation or activity.**

[illegible]

UW- River Falls Summer Physics Program Survey

*** 8. The teacher listens and uses student contributions whenever possible to build bridges to unfamiliar material.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 9. The teacher uses discrepant events to place students in disequilibrium, intentionally setting up situations where what the students observe is in direct conflict with what they believe should happen.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 10. When a concept has been thoroughly explored and discussed, the teacher provides opportunities for the student to apply the concept in a new way, or in a different context.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 11. Whenever material is presented, the teacher uses examples and situations that their students can relate to.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 12. The teacher simplifies and “restricts the frame” when introducing new material, adding more real-life elements later on as student understanding grows.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 13. The teacher takes the time to model for students how to recognize what is relevant and what is a distraction in a particular situation.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 14. When presenting material, the teacher uses multiple representations such as demonstrations, diagrams, graphs, equations, or other methods to convey the information.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 15. If using multiple representations, the teacher makes sure to teach the students how to translate between the various representations (Shifting from a graph to an equation or from a sentence to a graph for example).**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 16. Concepts are introduced multiple times, but with each new introduction, the context changes or more “real-life messiness” is added.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 17. The teacher has students demonstrate their understanding of a particular concept using a variety of representations such as written words, graphs, demonstrations, or other methods.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 18. The teacher uses varied teaching methods to address students' varied learning styles or multiple intelligences.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 19. The teacher uses varied forms of assessment to accurately measure learning for students with different learning styles or multiple intelligences.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 20. The teacher modifies lessons to respond to students' diverse cultural backgrounds.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 21. The teacher modifies lessons to accommodate students whose primary language is not English.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 22. The teacher modifies lessons to address students with special needs.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 23. Interaction between teacher and students is encouraged, and the students feel comfortable asking questions or discussing material with the teacher.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 24. Exploration of course material occurs in an interactive group format, such as small or whole group discussion.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 25. The classroom atmosphere encourages group approaches to problem solving.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

UW- River Falls Summer Physics Program Survey

*** 26. The teacher is an active listener, guiding only when necessary as the students generate and explore ideas.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

*** 27. The teacher has a framework in place to ensure that each member of the group is responsible for contributing to group products.**

	never				to a great extent	don't know
This happened during my training at UW-River Falls	☐	☐	☐	☐	☐	☐
I value this approach to introducing a lesson	☐	☐	☐	☐	☐	☐
I use this approach in my own classroom	☐	☐	☐	☐	☐	☐

Additional comments

28. If you are willing to be contacted by the researcher, please provide your email address (or other method of contact) in the space below.

Note: Providing this information does not automatically mean you will be contacted, it simply means you are giving the researcher that option.

UW- River Falls Summer Physics Program Survey

*** 29. Indicate your willingness to participate further in the study if asked to. This could mean a telephone interview or an exchange of emails to discuss your answers further.**

- ☐ Yes, I am willing to participate further in this study. (I have provided contact information).
- ☐ Maybe, it depends on the workload involved. (I have provided contact information).
- ☐ I may provide additional information, but don't think I am interested in participating any further than that. (I have provided contact information).
- ☐ No, I am not interested/able to participate further in this study.

Other (please specify)

APPENDIX D

ALIGNMENT OF UWRF-SUMMER PHYSICS PROGRAM SURVEY
WITH THE FIVE REDISH PRINCIPLES

Item #	<u>Question</u>	<u>Principle</u>	<u>Criteria #</u>
1	When a new topic is introduced, the teacher provides some form of engagement to arouse the curiosity of the student such as a demonstration, a thought provoking question, or a classroom discussion.	Constructivist	1
2	When a new topic is introduced, the teacher assesses students' prior knowledge to modify instruction.	Constructivist Change	1 1,2
3	Students explore concepts by gathering data and searching for patterns or relationships.	Constructivist	2,5
4	The students are encouraged to explain observations in their own words verbally, in writing or by other means.	Constructivist	6,8,10,12
5	The students are encouraged to justify or defend their points of view verbally, in writing or by other means.	Constructivist	6,10,12
6	Observations and experiments are often designed specifically to address common physics misconceptions. For example, believing a heavier object will fall faster than a lighter object.	Constructivist	1,3
7	The teacher acts as a facilitator, guiding students toward forming their own mental model of the observation or activity.	Constructivist	7,8,11
8	The teacher listens and uses student contributions whenever possible to build bridges to unfamiliar material.	Constructivist Change	4 2
9	The teacher uses discrepant events to place students in disequilibrium, intentionally setting up situations where what the students observe is in direct conflict with what they believe should happen.	Constructivist Change	1,3 5
10	When a concept has been thoroughly explored and discussed, the teacher provides opportunities for the student to apply the concept in a new way, or in a different context.	Constructivist	8,9
11	Whenever material is presented, the teacher uses examples and situations that their students can relate to.	Context Change	4,5 3,4

12	The teacher simplifies and “restricts the frame” when introducing new material, adding more real-life elements later on as the student understanding grows.	Context Change	1,2 3,6
13	The teacher takes the time to model for students how to recognize what is relevant and what is a distraction in a particular situation.	Context	3
14	When presenting material, the teacher uses multiple representations such as demonstrations, diagrams, graphs, equations, or other methods to convey the information.	Change	7
15	If the teacher uses multiple representations, they make sure to teach the students how to translate between the various representations (Shifting from a graph to an equation or from a sentence to a graph for example).	Change	8
16	Concepts are introduced multiple times, but with each new introduction, the context changes or more “real-life messiness” is added.	Change	9
17	The teacher has the student demonstrate their understanding of a particular concept using a variety of representations such as written words, graphs, demonstrations, or other methods.	Change	10
18	The teacher uses varied teaching methods to address students’ varied learning styles or multiple intelligences.	Individuality	1,2,3,4,5,7,8
19	The teacher uses varied forms of assessment to accurately measure learning for students with different learning styles or multiple intelligences.	Individuality Social Learning	6 6
20	The teacher modifies lessons to respond to students’ diverse cultural backgrounds.	Individuality	7
21	The teacher modifies lessons to accommodate students whose primary language is not English.	Individuality	7,8
22	The teacher modifies lessons to address students with special needs.	Individuality	8
23	Interaction between teacher and students is encouraged, and the students feel comfortable asking questions or discussing material with the teacher.	Social Learning	1

24	Exploration of course material occurs in an interactive group format, such as small or whole group discussions.	Social Learning	2,3
25	The classroom atmosphere encourages group approaches to problem solving.	Social Learning	2,3
26	The teacher is an active listener, guiding only when necessary as the students generate and explore ideas.	Social Learning	4
27	The teacher has a framework in place to ensure that each member of the group is responsible for contributing to group products.	Social Learning	5

APPENDIX E

SURVEY RESULTS SECTION I: DEMOGRAPHICS

Demographics Question	Choices	N	%	Average	σ
1. How many years have you taught?	1: 1 st year 2: 2-5 years 3: 6-10 years 4: 11-15 years 5: 16-20 years 6: 21+ years	0 7 16 16 6 9	0 13.0 29.6 29.6 11.1 16.7	Choice 3.88	1.27
2. What percentage of students in your building are eligible for free or reduced lunch?	7. 0-10% 8. 11-20% 9. 21-30% 10. 31-40% 11. 41-50% 12. Over 50%	11 15 12 5 4 7	20.4 27.8 22.2 9.3 7.4 13.0	Choice 2.94	1.64
3. How would you describe the school in which you teach in terms of student population?	9. 200 or less 10. 201-400 11. 401-600 12. 601-800 13. 801-1000 14. 1001-1500 15. 1501-2000 16. Over 2000	3 9 11 6 2 13 9 1	5.6 16.7 20.4 11.1 3.7 24.1 16.7 1.9	Choice 4.39	2.02
4. What percentage of the students in your class are not Caucasian?	11. 0-10% 12. 11-20% 13. 21-30% 14. 31-40% 15. 41-50% 16. 51-60% 17. 61-70% 18. 71-80% 19. 81-90% 20. 91-100%	39 3 7 1 1 2 0 1 0 0 0	72.2 5.6 13.0 1.9 1.9 3.7 0 1.9 0 0 0	Choice 1.76	1.53
5. What percentage of your students are male? What percentage of your students are female?	Male Female		50.8 49.2		
6. What percentage of students in your class have limited English proficiency?	7. 0-10% 8. 11-20% 9. 21-30% 10. 31-40% 11. 41-50% 12. Over 50%	51 1 2 0 0 0	94.4 1.9 3.7 0 0 0	Choice 1.09	0.40
7. How would you compare the achievement level of your students to that of other students in your state?	6. Far below 7. Below 8. About the same 9. Above 10. Far above	1 5 22 22 4	1.9 9.3 40.7 40.7 7.5	Choice 3.43	0.84
8. Please indicate which course(s) you have taken in the UW-RF program.	Mechanics Electricity & Magnetism Modern Physics Astronomy	39 45 36 20	79.6 86.5 70.6 43.5		

	Astrophysics	14	30.4		
	Acoustics	25	54.3		
	Optics	30	62.5		
	Laser Physics	12	27.3		
	Thermodynamics	19	39.1		
	Use of Physics Equipment/Technology in the classroom	14	32.6		
	Modeling	20	43.5		
9. What were your reasons for entering the program? (Check all that apply).	5. General interest	23	42.6		
	6. To maintain state licensure	21	38.9		
	7. To gain physics licensure	20	37.0		
	8. To Earn MSE-Physics degree	41	75.9		
10. What is your current status in terms of physics teaching?	6. Not certified, do not intend to become certified.	6	11.1		
	7. Not certified, intend to become certified.	9	16.7		
	8. Physics certified, not seeking MSE-Physics degree.	9	13.0		
	9. Physics certified, seeking MSE-Physics degree.	8	14.8		
	10. Physics certified with MSE-Physics degree.	24	44.4		
11. When did you take your most recent UWRF physics course?	11. pre-2001	4	7.4	Choice	2.81
	12. 2001	0	0	7.02	
	13. 2002	3	5.6		
	14. 2003	4	7.4		
	15. 2004	6	11.1		
	16. 2005	6	11.1		
	17. 2006	3	5.6		
	18. 2007	9	16.7		
	19. 2008	6	11.1		
	20. 2009	15	27.8		

APPENDIX F

SURVEY RESULTS SECTION II: REDISH PRINCIPLES

Principle Contstrv Context Change Individ Soc Learn	Question & Strand 2 = Happened during UWRF training 3= Value this approach to teaching a lesson 4 = Use this approach in own classroom		M	SD	Not at All 1	2	3	4	To a great extent 5
					n (%)	n (%)	n (%)	n (%)	n (%)
Constrv	1. When a new topic is introduced, the teacher provides some form of engagement to arouse the curiosity of the student such as a demonstration, a thought provoking question, or a classroom discussion.	2	4.04	0.92	0 (0%)	2 (3.7%)	15 (27.8%)	15 (27.8%)	21 (38.9%)
		3	4.70	0.54	0 (0)	0 (0)	2 (3.7)	12 (22.2)	38 (72.2)
		4	4.26	.68	0 (0)	0 (0)	7 (13.0)	25 (46.3)	21 (38.9)
Constrv Change	2. When a new topic is introduced, the teacher assesses students' prior knowledge to modify instruction.	2	2.85	1.16	4 (7.4)	20 (37.0)	15 (27.8)	6 (11.1)	7 (13.0)
		3	4.04	0.95	1 (1.9)	1 (1.9)	14 (25.9)	17 (31.5)	21 (38.9)
		4	3.57	1.09	2 (3.7)	6 (11.1)	18 (33.3)	15 (27.8)	13 (24.1)
Constrv	3. Students explore concepts by gathering data and searching for patterns or relationships.	2	4.23	0.87	0 (0)	2 (3.7)	9 (16.7)	17 (31.5)	25 (46.3)
		3	4.61	0.71	0 (0)	2 (3.7)	1 (1.9)	13 (24.1)	38 (70.4)
		4	4.35	0.83	0 (0)	1 (1.9)	9 (16.7)	14 (25.9)	30 (55.6)
Constrv	4. The students are encouraged to explain observations in their	2	3.92	0.97	0 (0)	4 (7.4)	14 (25.9)	16 (29.6)	18 (33.3)

	own words verbally, in writing or by other means.	3	4.52	0.77	0 (0)	1 (1.9)	6 (11.1)	11 (20.4)	36 (66.7)
		4	4.28	0.98	0 (0)	4 (7.4)	8 (14.8)	11 (20.4)	31 (57.4)
Constrv	5. The students are encouraged to justify or defend their points of view verbally, in writing or by other means.	2	3.74	1.02	0 (0)	9 (16.7)	9 (16.7)	22 (40.7)	13 (24.1)
		3	4.28	0.79	0 (0)	2 (3.7)	5 (9.3)	23 (42.6)	24 (44.4)
		4	4.00	0.97	0 (0)	5 (9.3)	10 (18.5)	19 (35.2)	20 (37.0)
Constrv	6. Observations & experiments are often designed specifically to address common physics misconceptions. For example, believing a heavier object will fall faster than a lighter object.	2	3.92	0.84	0 (0)	1 (1.9)	17 (31.5)	19 (35.2)	15 (27.8)
		3	4.41	0.71	0 (0)	1 (1.9)	4 (7.4)	21 (38.9)	28 (51.9)
		4	4.17	0.84	1 (1.9)	0 (0)	9 (16.7)	23 (42.6)	21 (38.9)
Constrv	7. The teacher acts as a facilitator, guiding students toward forming their own mental models of the observation or activity.	2	3.56	1.02	0 (0)	9 (16.7)	18 (33.3)	15 (27.8)	12 (22.2)
		3	4.20	0.88	0 (0)	3 (5.6)	7 (13.0)	20 (37.0)	24 (44.4)
		4	3.76	0.90	0 (0)	4 (7.4)	18 (33.3)	18 (33.3)	13 (24.1)
Constrv Change	8. The teacher listens and uses student contributions whenever possible to build bridges to unfamiliar material.	2	3.82	0.99	0 (0)	5 (9.3)	17 (31.5)	15 (27.8)	17 (31.5)
		3	4.39	0.76	0 (0)	1 (1.9)	6 (11.1)	18 (33.3)	29 (53.7)
		4	4.09	1.78	0 (0)	2 (3.7)	8 (14.8)	27 (50.0)	17 (31.5)
Constrv Change	9. The teacher uses discrepant events to place students in disequilibrium, intentionally setting up situations where	2	3.36	1.05	1 (1.9)	8 (14.8)	23 (42.6)	8 (14.8)	10 (18.5)
		3	3.86	1.08	1 (1.9)	6 (11.1)	10 (18.5)	18 (33.3)	18 (33.3)

	what the students observe is in direct conflict with what they believe should happen.	4	3.33	1.03	3 (5.6)	7 (13.0)	19 (35.2)	19 (35.2)	6 (11.1)
Constrv	10. When a concept has been thoroughly explored and discussed, the teacher provides opportunities for the student to apply the concept in a new way, or in a different context.	2	3.65	1.01	0 (0)	7 (13.0)	17 (31.5)	15 (27.8)	13 (24.1)
		3	4.30	0.77	0 (0)	1 (1.9)	7 (13.0)	21 (38.9)	25 (46.3)
		4	3.82	0.92	0 (0)	4 (7.4)	16 (29.6)	20 (37.0)	14 (25.9)
Context	11. Whenever material is presented, the teacher uses examples and situations that their students can relate to.	2	4.41	0.69	0 (0)	0 (0)	6 (11.1)	20 (37.0)	28 (51.9)
		3	4.82	0.39	0 (0)	0 (0)	0 (0)	10 (18.5)	44 (81.5)
		4	4.59	0.66	0 (0)	0 (0)	5 (9.3)	12 (22.2)	37 (68.5)
Context	12. The teacher simplifies and “restricts the frame” when introducing new material, adding more real-life elements later on as student understanding grows.	2	3.75	1.03	0 (0)	6 (11.1)	14 (25.9)	13 (24.1)	14 (25.9)
		3	4.14	0.90	0 (0)	3 (5.6)	8 (14.8)	18 (33.3)	21 (38.9)
		4	4.02	0.98	0 (0)	4 (7.4)	11 (20.4)	15 (27.8)	20 (37.0)
Context	13. The teacher takes the time to model for students how to recognize what is relevant and what is a distraction in a particular situation.	2	3.51	1.08	2 (3.7)	6 (11.1)	14 (25.9)	16 (29.6)	9 (16.7)
		3	4.04	0.90	1 (1.9)	1 (1.9)	10 (18.5)	21 (38.9)	17 (31.5)
		4	3.84	0.96	1 (1.9)	2 (3.7)	15 (27.8)	18 (33.3)	14 (25.9)
Change	14. When presenting material, the teacher uses multiple representations such as demonstrations, diagrams, graphs, equations, or other methods to convey the information.	2	4.40	0.86	0 (0)	3 (5.6)	4 (7.4)	15 (27.8)	31 (57.4)
		3	4.72	0.45	0 (0)	0 (0)	0 (0)	15 (27.8)	39 (72.2)
		4	4.52	0.64	0 (0)	0 (0)	4 (7.4)	18 (33.3)	32 (59.3)

Change	15. If using multiple representations, the teacher makes sure to teach the students how to translate between the various representations (Shifting from a graph to an equation or from a sentence to a graph for example).	2	4.00	0.99	1 (1.9)	1 (1.9)	16 (29.6)	13 (24.1)	21 (38.9)
		3	4.47	0.64	0 (0)	0 (0)	4 (7.4)	20 (37.0)	29 (53.7)
		4	4.28	0.69	0 (0)	0 (0)	7 (13.0)	24 (44.4)	22 (40.7)
Change	16. Concepts are introduced multiple times, but with each new introduction, the context changes or more “real-life messiness” is added.	2	3.47	0.99	1 (1.9)	7 (13.0)	18 (33.3)	17 (31.5)	8 (14.8)
		3	3.87	0.92	0 (0)	3 (5.6)	17 (31.5)	17 (31.5)	16 (29.6)
		4	3.64	0.86	0 (0)	4 (7.4)	20 (37.0)	20 (37.0)	9 (16.7)
Change	17. The teacher has students demonstrate their understanding of a particular concept using a variety of representations such as written words, graphs, demonstrations, or other methods.	2	3.89	1.05	0 (0)	7 (13.0)	11 (20.4)	16 (29.6)	19 (35.2)
		3	4.39	0.76	0 (0)	1 (1.9)	6 (11.1)	18 (33.3)	29 (53.7)
		4	4.19	0.78	0 (0)	1 (1.9)	9 (16.7)	23 (42.6)	21 (38.9)
Individlty	18. The teacher uses varied teaching methods to address students’ varied learning styles or multiple intelligences.	2	3.31	1.16	3 (5.6)	11 (20.4)	14 (25.9)	15 (27.8)	9 (16.7)
		3	4.33	0.84	0 (0)	2 (3.7)	7 (13.0)	17 (31.5)	28 (51.9)
		4	4.04	0.91	0 (0)	4 (7.4)	9 (16.7)	22 (40.7)	19 (35.2)
Individlty Soc Learn	19. The teacher uses varied forms of assessment to accurately measure learning for students with different learning styles or multiple intelligences.	2	2.77	1.03	6 (11.1)	16 (29.6)	16 (29.6)	14 (25.9)	1 (1.9)
		3	3.96	0.89	0 (0)	4 (7.4)	10 (18.5)	24 (44.4)	16 (29.6)
		4	3.57	0.89	0 (0)	7 (13.0)	14 (25.9)	28 (51.9)	5 (9.3)

Individlty	20. The teacher modifies lessons to respond to students' diverse cultural backgrounds.	2	1.98	0.85	14 (25.9)	15 (27.8)	11 (20.4)	1 (1.9)	0 (0)
		3	3.19	1.08	2 (3.7)	13 (24.1)	18 (33.3)	13 (24.1)	7 (11.1)
		4	2.65	1.00	5 (9.3)	20 (37.0)	16 (29.6)	8 (14.8)	2 (3.7)
Individlty	21. The teacher modifies lessons to accommodate students whose primary language is not English.	2	1.22	0.58	23 (42.6)	2 (3.7)	2 (3.7)	0 (0)	0 (0)
		3	3.45	1.26	4 (7.4)	8 (14.8)	11 (20.4)	14 (25.9)	12 (22.2)
		4	3.45	1.26	8 (14.8)	13 (24.1)	14 (25.9)	9 (16.7)	4 (7.4)
Individlty	22. The teacher modifies lessons to address students with special needs.	2	1.97	1.05	12 (22.2)	9 (16.7)	6 (11.1)	1 (1.9)	1 (1.9)
		3	3.96	0.97	0 (0)	4 (7.4)	13 (24.1)	16 (29.6)	19 (35.2)
		4	3.71	1.05	1 (1.9)	7 (13.0)	11 (20.4)	20 (37.0)	13 (24.1)
Soc Learn	23. Interaction between teacher and students is encouraged, and the students feel comfortable asking questions or discussing material with the teacher.	2	4.70	0.63	0 (0)	0 (0)	5 (9.3)	6 (11.1)	43 (79.6)
		3	4.89	0.32	0 (0)	0 (0)	0 (0)	6 (11.1)	48 (88.9)
		4	4.80	0.45	0 (0)	0 (0)	1 (1.9)	9 (16.7)	44 (81.5)
Soc Learn	24. Exploration of course material occurs in an interactive group format, such as small or whole group discussion.	2	4.13	0.95	0 (0)	3 (5.6)	12 (22.2)	14 (25.9)	25 (46.3)
		3	4.50	0.69	0 (0)	1 (1.9)	3 (5.6)	18 (33.3)	32 (59.3)
		4	4.28	0.90	0 (0)	3 (5.6)	7 (13.0)	16 (9.6)	28 (51.9)
Soc Learn	25. The classroom atmosphere encourages group approaches	2	4.19	0.99	0 (0)	4 (7.4)	10 (18.5)	12 (22.2)	28 (51.9)

	to problem solving.	3	4.56	0.74	0 (0)	1 (1.9)	5 (9.3)	11 (20.4)	37 (68.5)
		4	4.28	0.81	0 (0)	1 (1.9)	9 (16.7)	18 (33.3)	26 (48.1)
Soc Learn	26. The teacher is an active listener, guiding only when necessary as the students generate and explore ideas.	2	3.44	1.06	0 (0)	12 (22.2)	17 (31.5)	14 (25.9)	11 (20.4)
		3	3.91	0.92	0 (0)	5 (9.3)	10 (18.5)	24 (44.4)	15 (27.8)
		4	3.52	0.99	0 (0)	10 (18.5)	15 (27.8)	20 (37.0)	9 (16.7)
Soc Learn	27. The teacher has a framework in place to ensure that each member of the group is responsible for contributing to group products.	2	2.94	1.28	4 (7.4)	19 (35.2)	10 (18.5)	6 (11.1)	9 (16.7)
		3	3.91	1.03	1 (1.9)	5 (9.3)	10 (18.5)	20 (37.0)	18 (33.3)
		4	3.35	1.08	1 (1.9)	13 (24.1)	15 (27.8)	16 (29.6)	9 (16.7)

APPENDIX G

CASE STUDY INVITATION

Dear UWRF Summer Physics Participants,

First of all, thank you so much for participating in my dissertation survey. Your unique insight will prove valuable in providing information to the physics education community as to what really works in a high school physics (or physical science) classroom.

I am writing you today, because you indicated a possible willingness to provide more information with regards to this study. I am not sure as of yet exactly what I will ask of you in the future, but I assure you that I will do my best to keep your workload to a minimum as I gather information.

Right now, I believe that at some point I will ask to interview you, either by phone or in person (and I think I'll probably send you the questions I plan to ask in advance to speed up the process so I don't take up too much of your time). I will probably also ask for examples of a lesson or two where you demonstrate how you incorporate what UWRF taught you into your classroom and employ some of the techniques mentioned in the survey. There is a chance I may also ask to come and observe you in your classroom as well, but I have not made a final decision as to whether this will be necessary.

If you are still interested in participating on some level, what I am asking you to do right now is write a paragraph or two about what you teach, your comfort level with high school physics (or physical science), maybe a little about how you feel about UWRF... basically just a little more about who you are, and what you believe about teaching physics. I will submit this information to my major professor, and between the two of us, we will decide how to proceed further. Tell your story, and don't be afraid to say what you really think. If there are parts of the program that you like, say so... if there are parts you dislike... ALSO SAY SO ☺. It is very important that I have the chance to tell the whole story, and my ability to do so is heavily dependent on what you choose to share.

I am not sure about this yet, but there may be a small cash stipend available for your participation in this study. When I know more, I will let you know.

This does not have to be a novel, I know summer is here, but just a little more info about you that I can share with my major professor as we make the final decision about case study participants. Please email your information as soon as you are able ☺

THANK YOU AGAIN FOR ALL THAT YOU DO!

Sincerely,

Randy Ketola

ketr@richland.k12.wi.us

rgketola@hotmail.com

608-647-9818

APPENDIX H

CASE STUDY INTERVIEW FORMAT

Case Study Interview Questions

Part I: Teacher background prior to entry into UWRF program

1. Do you have professional experience in fields other than teaching? If “yes”, tell me about these experiences and when they occurred.
2. Since becoming a teacher have you always taught physics? Please explain.
3. What were the influences that led to your teaching physics?
4. How well prepared did you feel initially to teach physics?
5. In what ways, if any, did your perception of your ability to teach physics change after you began teaching the subject?
6. What led you to the UWRF Summer Physics Program? Why did you decide to look into the program? To enter the program?
7. If you completed undergraduate or graduate physics courses before joining the UWRF program, how did these earlier experiences compare to those at UWRF?
8. Specifically, please compare:
 - a. The course structures or formats.
 - b. The content focus, including the importance placed on different aspects of physics.
 - c. The teaching styles of the instructors.
 - d. The size of the classes
 - e. The accessibility/availability of the professors
 - f. The laboratories and investigations.
(*Probe: Please describe the approach used to investigate a specific topic in your earlier coursework compared to UWRF.*)
 - g. The atmosphere, including the frequency and types of interactions among the participants.

Is there anything else you would like to mention?

Part II: Evidence of carry-over from the program into the classroom.

9. In what ways have students’ experiences in your class changed as a result of your participation in the UWRF program?

- a. For example, in what ways have their lecture experiences changed?
 - b. What about laboratories or other inquiry experiences?
 - c. Student experiences in whole or small group discussions?
 - d. Other small group activities?
 - e. The nature of students' homework?
 - f. What about the assessments students complete for your class?
10. What aspects of the UWRF program have you found it relatively easy to carry over into your own curriculum and classroom? (Probe: Why were these easier to import?)
11. What aspects of the UWRF program would you like to carry over into your curriculum and classroom, yet have not been able to thus far?

What has prevented this from happening?

What solutions are you still considering?

12. Are there any teaching methods/practices that you value and use that are not part of the UWRF program? If so, please describe.

Part III: Focus on participant beliefs and practices regarding teaching physics.

13. Please you give an example of how you typically begin a new topic.

Probes:

- a. How do you initially engage your students?
 - b. How and when do you assess student prior knowledge of the material you are teaching?
 - c. How do you lead your students from familiar to new material?
 - d. How do you address misconceptions or faulty reasoning?
 - e. Do you introduce all of the variables in the lesson at once, or more gradually?
 - f. How do you decide which variables come first?
 - g. How many different ways do you represent the material? Can you give me some examples?
 - h. How do you translate between representations, can you give me some examples?
14. Please walk me through a typical physics investigation in your classroom.

Probes:

- a. How does the investigation typically begin?

- b. How much information is introduced prior to starting the investigation?
 - c. Do the students pick their own lab groups or do you assign them?
 - d. Are they always in the same groups?
 - e. Are the investigation procedures spelled out, or do the students have latitude in how they set things up?
 - f. As the students are investigating, what is your role? How do you interact with the students while they are ~~taking~~ collecting data etc...?
 - g. How do students typically present their findings?
 - h. Is this the same for most investigations, or do you invite students to present material in multiple ways?
 - i. What are some of the other ways they present?
 - j. How is their work assessed?
 - k. How do you determine if students have met the objectives of the investigation?
15. Please describe the classroom space, equipment and other resources available to you for teaching physics.
16. Are these adequate given the kinds of learning experiences you would like to provide for your physics students? Please explain.
17. Please describe your overall approach to assessing your students' physics learning.
- Probes:
- a. What kinds of formative assessment do you use while students are still investigating a particular topic?
 - b. What about summative assessment once instruction has concluded?
 - c. How do you assign grades for a unit or term? For example, what counts toward the grade and for how much?
 - d. What strategies do you use for assessing students' prior knowledge?
 - e. Do you adapt assessments in any ways for different learners? Please describe).
18. By the end of a physics course, what do you hope to accomplish with your students?
19. How do you know whether or not you and your students have reached this goal?
20. Is there anything more you would like to say about your experiences in the UWRF program?
21. Is there anything more you would like to say about your knowledge and experiences as a physics teacher?

Thank you very much for your insights and time.

APPENDIX I

CASE STUDY INTERVIEW TRANSCRIPTIONS

Interview 7/13/2010

Steve

I: The first question I've got for you is do you have any professional experience in fields other than teaching? Did you do anything else professionally prior to becoming an educator?

R: No, teaching was my first career.

I: Okay. When you became a teacher, since the first time you started in teaching, have you always been a physics teacher?

R: No, actually my first year teaching was chemistry and physical science.

I: Okay, and then how many years into it were you before you started teaching physics?

R: I moved to Verona after my first year, and I started teaching physics at that time.

I: Okay, so you taught other subjects for one year, and then physics you started up your second year?

R: Yes.

I: What led you into teaching physics? Was it your decision, or was it--? What circumstances led you to being a physics teacher?

R: Actually, physics was one of the classes that was part of the job if I wanted to come to Verona. I always did love physics, and I was looking to do physics, and that was something that was a nice perk of the job.

I: Okay, so you knew that coming in, that that was going to be something that was expected of you?

R: Yes.

I: Alright, if physics hadn't been part of the job description, would you still have taken the position do you think?

R: Yes I would have. Actually my area of emphasis in college was in chemistry, which is very close in the state of Iowa to an emphasis in physics. It's only off by a couple classes so I still would have done it if it would have only been chemistry, but I have never regretted taking on the physics load.

I: So, when you started physics then, your second year as a teacher, how well prepared did you feel, you know before day one when you were walking in, how confident were you in your abilities?

R: On a scale of 0 to 10, probably 0.

I: Okay (laughter from both). Explain.

R: I could read through the material, I could help the students with it, but I honestly, I didn't have a firm grasp of the physics concepts. There were a lot of things where I knew that "this was the equation we used, and this is how we used it", but I didn't really have an understanding of how everything related to one another until I started teaching it for a couple of years, and then especially through the physics program at UWRF. That's where I really started to really understand what I really was teaching.

I: So you knew before you started that it was probably going to be a struggle?

R: Yes. Yes.

I: Okay, because some people say that they thought that "Oh, it was going to be a piece of cake" until they actually get in there and try it. So, during just your first year, did your perception about your ability to teach physics start changing, or was it pretty much that first year it was just the way you initially described it for that whole first year?

R: The first year, I wouldn't say it was horrible, it was a definite learning experience where I really started to learn the things that I didn't know, which as a teacher is a good thing, because if you know these are the things that I really don't know, then you've got something to focus on, something to shoot for, to be able to understand them and be able to help students understand them better.

I: Okay good. At what point now, this is your second year as a teacher, you're teaching physics this year, what led you to the UWRF program?

R: Actually, it was one of their fliers that I had seen. I knew that I needed some credits, and it looked like it was—at first it was a good cheap way to get a couple of credits and for the state of Wisconsin, I still needed a couple different things to become physics certified, and it was a great way for me to get my certification. And after I took my first class there, that's where I really, really saw the value in the program and knew that I was going to finish out the program.

I: Now, you might have already said this earlier, but that first year, you were teaching in a different state?

R: Yes, I was teaching in Nevada my first year.

I: I guess I knew that. Yeah, okay. So, you were in Nevada first, and so when you transitioned to Wisconsin, their licenses don't match up exactly right...

R: Yes, yup.

I: Okay, so you found a flier, and you decided to give this program a chance, and I think what you said was as soon as you got in there and saw the way things were, that you knew right away that this was something that you wanted to...finish.

R: Oh, definitely.

I: So, if you had completed undergraduate—I guess for you it would have been undergraduate level physics courses before UWRF at—I think—did you go to [a large Midwestern university]?

R: Yes, I went to [that university].

I: Okay, if you had—

R: I took a number of undergraduate physics there.

I: Alright, so you took those classes at [that university]... how did those classes compare to what you experienced as a student at the UWRF? Is there anything you could say comparing one to the other, similarities, differences, whatever?

R: I would say that the courses I took in college, I did well in them, I studied hard, I was able to answer questions on the test about the concepts, but I didn't truly have an understanding of how the concepts related to one another, and how I could help other people understand those concepts. And I would say the UWRF program was one that really taught me how all the concepts related to one another, and how I could help the students understand those relationships a lot better than I had been in the past. It made me a lot more comfortable with what I was doing.

I: So, were the courses structured different? Like, maybe the atmosphere, what the professors stressed, were they different from your undergraduate versus River Falls?

R: Sure, the River Falls program, we were a much smaller cohort, I think there were probably 25 of us in there, or something like that, and we had more one on one attention with the professors, and at the University of Iowa, it was still a great program, but during our lecture session, we would have 150 students in the lecture, and if you wanted to ask a question, you had to meet with a professor during his office hours and it wasn't as conducive I would say to really understanding everything. I could spit back what they spit out at me, but I didn't really have an understanding of what I was writing down on the page.

I: So, what I'm hearing is you were able to pass the tests, and it probably looked good on a worksheet, but you didn't really feel like you had a—say the grasp that you have now looking back with the years of experience you have now.

R: Yes, definitely yes... I didn't have that then.

I: Sure. Did you feel that the instructors in one program versus the other—did they focus on content differently? In other words, your undergraduate professor, what they thought was important and what they went after versus what the River Falls program professors thought was important and what they went after? Did you notice a difference in where the emphasis was placed?

R: Slightly, a little bit. It's really hard to compare the two of them because the courses I took at my undergraduate university were all calc based and so we learned the calculus of physics, and I would say there was a lot more emphasis on how to do the equations and how to solve the problems mathematically, rather than concept oriented, which I think courses at UWRF were more about the concepts and the math was there on how to solve problems dealing with the concepts.

I: So it was maybe more of a shift from a numerical manipulation to more of a “what's really going on here... take the numbers away?” Although they did take the numbers into account, didn't they (laughter)?

R: We had numbers. We had lots of numbers (laughter).

I: What about the teaching style of the instructors? The way that they engaged the students and what they asked the students to do maybe?

R: I would say since it was definitely a smaller class, I felt with the UWRF program... I felt—I don't want to say being pushed in a bad way, but being pushed in a good way to do as much as I could, and to really understand the material, and to really keep pushing myself.

I: Did you feel like the instructors maybe paid a little bit more attention to you in one program versus another... you as an individual?

R: Yeah, definitely. At the UWRF program, a lot more attention was paid to me as an individual. At the University of Iowa, it was still a very good program, but dealing with the large number of students that they deal with, you're not just a number, but it's more in that range where they have to deal with so many people they can't give you as much individual attention.

I: You've mentioned it several times, did you feel that the smaller class size was a benefit?

R: Much, yeah. It was a great benefit, yeah.

I: We've kind of danced around this, too, but comparing the two programs. The accessibility and availability of the professors—maybe their availability and willingness to reach out—or maybe that's two separate issues; availability and willingness?

R: I would say both, I would say the professors at UWRF were much more available to us -- I can't say my professors and I at my undergraduate university ever hung out at Bo's and Mine on a Friday night (laughter) I can't say that.

I: So you never saw your [undergraduate] professors in a social setting?

R: No. No. And it was much more—since I was an undergrad in college it was more student professor relationship rather than—not really colleague-colleague relationship, but I felt more of that in the UWRF program. Our two professors saw us as the teachers and professionals that we were, and they saw how they could help us out as professionals rather than I am the professor and you are the lowly student.

I: And you haven't really come right out and said it, but are you meaning that maybe in some of those undergraduate classes where they talk about the—it's almost like a survival of the fittest whereas—

R: Oh yeah, definitely.

I: In this program, you didn't feel like you were—did you feel like you were competing with the person sitting next to you?

R: No, I didn't feel like I was competing with anybody in the UWRF program. We were all there to become better physics teachers. That was the goal for everybody there and our professors there did a great job of spending just as much time with the person that knew the material and wanted to learn extra, as with the person that was really struggling and needed the help. I feel like everybody got what they needed and what they deserved out of the program.

I: Cool. So now, do you remember back to when we used to do the lab work?

R: Yeah.

I: And do you remember back to doing your lab work back at the University of Iowa?

R: Um hmm.

I: Compare the experience of going into a lab at Iowa versus going into a lab at River Falls.

R: Well, the labs at Iowa were good labs that helped me understand the material a lot better, but I'd have to say that the structure of the labs at UWRF was a lot better for actually understanding the concepts and how to solve problems that deal like—my labs at my undergraduate university were more of the “follow the directions precisely, get the results, post the results” whereas at UWRF we had to really figure out exactly what our problem was, how we were going to solve it, and then actually going about solving it.

I: Do you remember any specific lab—a specific lab that maybe you did at Iowa and you did again at River Falls—a specific experiment? I'm kind of putting you on the spot, that was a few years ago. (laughter)

R: Um, I can't remember if we did—did we do resonance tubes at UWRF? I think we did in our acoustics class?

I: In acoustics you would.

R: Yeah, I did that lab in both. Where we did the resonance tubes and we looked at resonant frequencies and stuff like that. When I first did it as an undergrad, I was just taking down numbers, and putting numbers into equations and coming up with an answer, and that was it. I didn't really understand what I was doing, the whole concepts that were involved, whereas, going back through the second time at UWRF, I was able to really concentrate on all the concepts and knew exactly what we were doing then.

I: Do you think part of the reason why the labs spoke to you more at River Falls—do you think part of it was familiarity because you had gone through it before?

R: Oh that was definitely part of it. Part of it was I had a good background from the stuff that we had done before; that was definitely a part of it. But then the way that they were also organized and what was expected out of us, that was definitely something that helped as well.

I: And now that you've taught a number of years, and you look back at the way the labs were presented in one program versus another... if there was a brand new person thinking about wanting to be a physics teacher, could you see an advantage of taking one path versus another, if the person knew ahead of time that they wanted to be a physics teacher?

R: As far as like which way to set the labs up? I'm not sure I understand--

I: If you had a young student in your class that said “I want to be a physics teacher, where do you think I should go, I’m down to two choices; someplace like University of Iowa, or UWRF, and I want to be an physics educator”—You went through both experiences, if you knew ahead of time that this person wanted to be a teacher... does one program stand out—more geared toward preparing somebody to be a teacher more than the other, or would you say that it probably wouldn’t matter?

R: I’d have to be honest, I wouldn’t – I know a lot of things have changed at UWRF and I don’t know who the new instructors are there, and I didn’t go through their undergraduate program to know how their undergraduate program stacks up with other undergraduate programs. That’s one of the things I would really like to learn more about, is how those different programs stack up to one another so I could help students. I don’t feel like I’m able to say one way or another right now.

I: Okay. Is there anything else you’d like to mention about the program; good, bad, or ugly, that didn’t come up in these questions?

R: (Long pause) There was nothing ugly about it at all. I think it was a great experience, I think the fact that we were able to learn so much without having to shell out thousands and thousands and thousands of dollars every single summer we were—

I: Explain that. How did that work?

R: How would what work?

I: Well, you said that we were able do it without having to shell out thousands and thousands and thousands of dollars—

R: Well, I think that the program being offered with the grants that were available... I think that was a major reason why I was able to go through the program. I honestly don’t know if I would have—I probably wouldn’t have finished out the program if I would have had to pay full price for every single credit that I took. I absolutely would not have been able to do that. At the time, beginning teacher, struggling to pay all my bills and everything... I was looking for free credits out there and that was one of the things that brought me toward the program.

I: Excellent. Alright, so this next series of questions is going to help me get a feel for what you’ve been able to pull out of this program and then bring into your classroom. Would you say that—and you started it so young in your career so this might be kind of hard to answer, but do you feel that your students’ experience in your class changed as a result of your exposure or participation in this program?

R: Most definitely.

I: Let's pick it apart piece by piece. How did your lecture change after you had some exposure to this program?

R: Basically, when I started, the night before, I would sit down, I would read through the physics book, and I would say "Okay, this is what's in chapter one, and this is what we have to do for tomorrow, and here's how much we can get through, and here are a couple of practice problems, and I'll try to work the problems in front of the kids, and then I'll let the kids work"—and it wasn't really conducive to the kids for understanding concepts so much. I think that they were able to sit down and solve a problem like I had solved a problem, but they didn't really understand that there were many different ways to solve a problem, and they weren't; the ones who were coming up with the ways to solve the problem. I was doing it for them.

I: So initially, your lecture was kind of more like the students would sit and get, and you would show them one way to do it (R: yes, yes) and they would learn to do it that one way, but maybe (R: uh huh) okay— but maybe not be able to blaze their own path and take an alternative path (R: uh huh)... Alright—

R: I'd say now it's changed there are times that—we still do a lot of problem solving and things in my class, and I kind of model a lot of my stuff after what we had done in our program. With my problems, I actually give the problem sets out ahead of time for the whole unit that we are covering, and then as we are working on it, the kids are working on those problem sets, and I'm finding that the kids are finding really cool ways to solve problems that I hadn't thought about before. It's a lot of fun having the kids show each other going about solving the problems.

I: You're open to that? Kids coming up (R: oh yes) with alternative ways to solve problems?

R: Definitely. As long as it works for all circumstances, it's not just a specialty in this case that "hey it worked this time and may not work next time," yeah definitely, I've actually learned a lot from my students about different ways of thinking about problems.

I: Cool. And you attribute that a little bit maybe to some of the alternative ways that you were shown how things tie together while you were part of the program?

R: Oh yeah.

I: Now, think about your physics labs, and think about the way that you thought a lab should run, or maybe the way you ran them prior to having the training in the River Falls program and the way that you ran your labs—the way that you structured them after—during or after. Were there any significant changes there?

R: Yeah. Really significant changes. My first year of teaching physics was—the labs we did straight out of the textbook or straight out of the lab book that we got from the textbook company. And those types of labs were basically fill in the data sheet as you go along, and spit out an answer when you get done. Now, a lot of the labs that we do take many of the different concepts that we've been learning about and I give the students a problem that they have to figure out how to solve the problem, what materials they are going to need, how they are going to do it, and then actually come up with some type of solution to their problem.

I: So, if I'm hearing you right, your labs are more open-ended now than they were prior—

R: Yes, most definitely. And there are still times when we do things that aren't open ended. There are still times where we're looking for a specific answer or a specific way of doing something, but I would say in general, the trend I've seen in my labs is that they have become a lot more open ended.

I: Excellent, I think I'm going to ask you a question or two about that later, so I'm going to come back to that a little later. How about the level of discussion in your class? Whether it be small group or whole group... do you feel that the level of discussion and maybe the depth of discussion have changed as a result of your exposure in the program?

R: Yes, definitely. Since the lab has become more open ended, students are having to solve problems-- come up with different ways of solving problems, and in that process, I'm actually able to see where students' misunderstandings lie a lot more than I was able to in the other one. If you just give problems straight out of the textbook and give labs straight out of the textbook, they are either going to have a right answer, or they are going to have a wrong answer, but you don't really know what they're learning and what they're not learning. By being more open-ended, you really start to find out what their misconceptions are. And once you find those misconceptions, you can find ways to help students clear up those misconceptions. Otherwise, you can't.

I: This is off the beaten path now, I'm off my interview page a little here, but I've got to ask since you used the word misconception—Do you find as a teacher that it's easy to get a student to let go of a misconception or—

R: Oh no, it's hard (laughter)! It's tough. There are certain circumstances where you can show definitively that their misconception is wrong, and students will not let go of it. They can do five different lab activities that show then that their misconception is wrong and they'll still hold on to it.

I: I will tell you that I brought that up because the research that I'm doing and the years I've had in the classroom—I just wanted to get some more verification that that's – that's what they say, too (R: oh yeah) that it's really hard to get them to let go.

I: Are there any other small group activities that you have the students participate in that maybe have changed as a result of the time you spent at River Falls?

R: Oh sure, it's not all set up that way, but with the way the problem sets are given out ahead of time and everything... I have a lot of student collaboration, you know working with each other—kind of like what we did at River Falls where a lot of us would sit down and work through the problems ahead of time. And I get a lot more collaboration I think being more open ended than having students trying to compete against one another to see who is the smartest.

I: You've noticed a little bit of a shift in the attitude then?

R: I would say yeah, definitely.

I: Do you feel like getting rid of the competitiveness as you put it—do you feel that has increased or decreased the level of participation among all of your students as a whole?

R: Oh, I'd say it's definitely increased the participation. We haven't really gotten rid of all of the competitiveness, we still do things where we have students working in groups and they're trying to solve a problem, and it actually kind of becomes a competition, but it's not a competition you get an A and you get an F if you're on one side, and you're on the other side. The students just kind of get a kick out of – we've done one in the past where they have to roll an egg down a ramp and it has to go off at an angle, and the instructor walks underneath it at a certain speed, and they have to try to hit the instructor on top of the head, and it becomes a competition to see who can hit me on top of the head, definitely.

I: Oh, have you been hit?

R: Oh yeah, every once in a while.

I: Good stuff. What about the level of the homework, or the type—does the homework that they have now—I know you mentioned you give them the problem set ahead of time. Does the homework now look the same as it would have had you not taken this program? And if so, how is it different?

R: I would say that the biggest way that it's different is since I'm much more comfortable with what I am teaching and since I have a much better grasp of what it is I'm teaching, I'm able to pick a better representation of problems that really represent the concepts that we are learning, and help me figure out if the students understand the concepts, and I think also help students understand the concept as they are going through the problem. So it's not just going through and doing all the odds in the textbook. It's picking and choosing, and adding a lot of my own questions. So I haven't given up the

textbook, I think it's a good thing, students need to learn how to use a textbook, they're going to use them in college, so we do use them, but it's more just a tool, rather than this is what we're learning now at this time, and we have to follow everything in order and all that.

I: Do you specifically pick and choose problems that you know are going to address a misconception (R: Yes) or bring up something where—rather than them just getting a right answer, they're going to actually have to know it on a little deeper level—do you specifically hunt those problems out from time to time?

R: Definitely.

I: Is that something you did before?

R: Not as much, because I was still struggling with the material myself, so I still had—I still do have a ton of misconceptions—we all do (laughter)... (I: Amen) but I had millions more misconceptions before that ... and I didn't realize that... I had... all these misconceptions and I don't really understand the material. Now that I have a better grasp of it, and since I've been through it, where the students are, I have a better idea of where their misconceptions are probably going to lie, and I'm more able to pick questions that are able to address those misconceptions.

I: Excellent. So, along those same lines, I guess this ties in real close. Your assessments—did they change as a result of the program, or do they pretty much look like they always have?

R: They've changed, definitely. I still model all of my exams after the exams we took at UWRF. I really liked the format. I do—half my test is conceptual questions, that address all the concepts of the unit that we're in, and then I usually do something like answer 5 out of the 7 following questions where you can mathematically come up with an answer because I think that math is an important part of physics. It's definitely, I would say, the language of physics, how we do it. And so it kind of gives the students a chance to really show their understanding, and by picking 5 out of the 7, they can always take a couple that—they may actually understand the concept, but they may be missing just a piece. Because I know that had happened for me a lot of times. I understood the concept that was going on, but I was just missing one simple piece that would not allow me to solve the problem, and if I were not to have the option of going past that one, that one tiny little piece would really have knocked me down a lot.

I: The missing the piece part, and I have memories of that myself (laughter), do you believe in partial credit for problems that are multiple steppers?

R: Yes. Yes. Most definitely. That was one of the nice things we had at the university [of Wisconsin River-Falls] as well, was having the option of being able to show that you

understand—I always tell my students “I’m not trying to find out what you don’t understand, I’m trying to find out what you do understand, and the more you can show me, the more credit I can help you out with.” Because I’m not looking to take points away from people, I’m trying to give points for showing that you understand a concept.

I: Did you feel that the [UWRF] program had a similar philosophy?

R: Yes, yes.

I: Okay, so, looking at everything that was done up there, the labs, the lecture, the—all the components, the sharing sessions and what have you, what aspects of the program specifically at River Falls have you found it relatively easy to carry over into your curriculum and your classroom? What were you able to implement instantly with very little effort?

R: I would say there were a lot of things that I was able to implement right away. My testing structure was one of the things that was implemented right away, I’d say that the lab structure was one thing I was able to change right away. Since I was a young teacher and I hadn’t been teaching it for a long time, I didn’t have a set way of doing it, it was a lot easier to change what I was doing than if I had been doing the same thing for 20 years. Sometimes if it becomes engrained, it’s kind of hard to change what you are doing.

I: This is hypothetical, and that’s a really good point that you brought up. Lets say that you had been somebody who taught for 20 years a certain way, whatever way, and then you went to River Falls and you saw a different way, do you think it would be more challenging for the 20 year teacher to let go of what they did and embrace something new?

R: I would say it would be more challenging, but, I also saw that it was done. There we a lot of teachers there who had been teaching for 20+ years, and they took a lot out of the program and changed what they had done. I think everybody can do it. It’s just probably not quite as easy, you have to go into it with an open mind.

I: Was there anything in the program that you saw, and you thought “Man, I’d love to do that” but to date, you haven’t been able to make it work, you haven’t been able to carry over the transition?

R: Oh, there were some of the lab activities that we did in a few of the classes that were just... there’s no way I have the budget for any of those materials to do that kind of stuff, but I would say that some of that stuff was really really really cool, and I enjoyed it tons, but I’m just not able to do it budget wise. But there are things that budget-wise, I thought were going to be impossible, but I think one of the things we learned there was to just keep piecing things together, a little bit at a time, and eventually you’re going to have something pretty cool.

I: Have you been able to do that in the school district you teach in?

R: Yeah, right now, I just keep putting little things together and we have a classroom set of Lab Pros now with a lot of different things we can do with them. Where, when I started, I thought, “there’s no way we can afford any of this stuff”, but if you start piecing it together a little bit at a time, and you find a little money here and you find a little money there—it’s getting harder and harder to do now, but it’s still possible.

I: Is there anything specific you’ve done to be able to generate the funding for your personal program?

R: Not really. I know that at first when the budgets weren’t quite cut back so far as they are now, when we had a little bit more room—one of the things I learned at the program was come up with a list, and take the list at the end of the year (I: Laughter) to your principal and say “If there’s any money left, here’s my list” and I actually got quite a bit of stuff by doing that the first few years, but it doesn’t seem to be working much anymore (Both of us laughing hysterically).

I: Okay, that’s interesting. I vividly remember that also. Jay Zimmerman was always an advocate of (R: Yes. Yes.) keep a list on your bulletin board. Yeah. That’s interesting, because I still hear him saying the same thing. Is there anything that you do, that you’ve learned, that you’ve picked up that you love and you know that works that wasn’t stressed in the program?

R: (Long pause). I would say there have been some things that have changed since we’ve been in the program that I use a lot more now. I use a lot more Internet based stuff now than when we started the program [but] that’s just part of the times, that’s just the way it’s going. We had access to the Internet when we were working through the program, but there wasn’t a lot out there that was really Internet based, and now I’m using a lot more—I have my own website now where instead of writing stuff on the board, pretty much it’s all posted on there. Students can go check it out. All the assignment dates, all that, it’s all posted on there, so there are a lot of things that I’m using that way that I think is beneficial to me in saving time, and for the students it works out well. We did not use this in the program but my guess is probably that they’re talking about it now.

I: Well, I’m glad you brought that up, because that’s something I hadn’t really considered yet, but I have a new question for Dr. Korenic now about whether or not they have implemented the Internet things more, because you’re right, it was marginal 12 years ago, but that was 12 years ago. Thank you for that, that will give me something else to ask her.

I: So now, let’s wander into your classroom (R: Sure). Pick any topic in your mind right now that appeals to you, and explain to me as best you can, “How do you typically begin a new topic?” Let’s say you had just taken a test on a former chapter, and gone over all

of that and you're starting something else... or it's the beginning of the year. How do you initially engage your students?

R: As much as possible—it doesn't always work out this way—but as much as possible, I try to present some type of problem to the students. It may be conceptual, it may be mathematical, and it's something that ties in with what we're going to be learning about—and sometimes pose some kinds of questions to the students—sometimes, it may be a lab activity, sometimes, it was simply be some kind of hypothetical problem for them to sit down and try to solve with each other. We come up with several different answers, and we talk about those answers, and a lot of times that leads directly into what we're going to start talking about, whether that be a lecture on the concept, or whether it be showing how to solve different aspects of certain problems, it usually leads with some type of question.

I: Okay. When you're formulating that question, how much time do you put into thinking about the context, meaning your student population, what's familiar in their world, do you take that into consideration as you formulate that question or—?

R: I find myself doing that more and more now, because I think the times are changing, and what the students are exposed to is way different than when I had learned the material. There are just certain things that our students never experience. We're starting to get into students now that never knew a time before there was Internet, or before everybody had a cell phone or other things like that. And so, I definitely have to look at what is relevant to students now, and try to come up with things you can present to students that are relevant to what their lives are right now.

I: And so that is part of your thought process when you're coming up with (R: Yes) when you're coming up with what your initial pitch is going to be?

R: Yes, and sometimes, it doesn't quite work out that way. I think that I've thought about everything, and then all of a sudden I'll have this look on the kids' faces like "I have no clue what you are talking about right now (Laughter)." And the nice thing about it is, my students feel they can tell me I'm being a bonehead at any time. I try to have that type of relationship with my students that if they don't understand something and they know they're not getting it in a context that is relevant to them, they can say "Hey, this means absolutely nothing to me right now." And then we can sit down and we can discuss why, and we can figure out exactly "Oh, you're right, I haven't thought about it that way."

I: So, once you figure out – Is there a point in your lesson when you try to figure out what the students know already—you know, their prior knowledge before you try to wander off into unfamiliar territory, is there a method or a certain point in a lesson where you try to figure out what they're bringing to the table?

R: Yeah, usually, during a class we try to do several different things during a class. One of the things I like to do if we're learning about a concept that has different equations that we're using, whatever it may be, I like to, after we've gone through a few things, I like to give the students a little bit of time, and present another question to them that may be similar, but doesn't have exactly the same stuff that we're using to see if they understand the concept. One of the things that I really like to use that I don't use all the time, but I think one of my goals this next year is getting back to using it more, is using my set of whiteboards that I built with Jay Zimmerman when we were in the program. I think that's a great way of assessing student understanding like right now. Another way that I started with this year that I thought it was going to just be kind of a gimmicky thing, but a friend of mine showed me a website called "Pole Everywhere" where you can come up with a pole. If you have an overhead projector, you can project the pole onto the screen, and the students take out their cell phones, and they answer questions to that pole, and that gets sent to the computer program, and then in real time, it shows you all the answers to the pole. And I've actually found that I've had—it's brought up a lot of really good discussions that would have never come up before if we hadn't been doing it. And what I thought was going to end up being a gimmick, the kids really like, and it seems to really have increased their understanding.

I: Oh, and when you say it's increased their understanding, is that documented, or is it kind of your perception?

R: It's my perception. I mean, I haven't done a study on it, so I couldn't say definitively that it has, but as part of the discussions that have come up, it's cleared a lot of misunderstandings that the students have had, and I have a feeling that they're doing a lot better at it. I've never done the exact study of it. That would be a good study for somebody to do though.

I: Okay, lots of work out there. That's excellent. So, if your students know something and they know it well, and you want to take them from what they know to maybe what they don't know, do you have a specific tactic you use to lead students from the familiar to the unfamiliar?

R: I don't have a specific tactic. I'm kind of a person that tries to get to know everybody, and tries to get to know what things will help each one of the students out. Each student is different. There are some students that you can just keep throwing stuff at them and they'll just keep eating it up, and then there are other students where they'll just kind of shut down, and you have to find other ways of pushing them and showing them new material.

I: Do you find that you differentiate for students that way? You had said just now that you take time to get to know them, and that each student is a little different. Is that something that you find you do often? Find a little bit different way to present to different types of students?

R: Yeah. With a lot of students that—We have difficult concepts that we're trying to learn. And the way I try to set the class up is so that each day we have some individual time in the class where we can sit down and I can talk with the kids individually about what we're doing. There are times where I will show one way of solving a problem to one student, and I'll show a totally different way of solving a problem to a different student because when you get to know the students, you have an idea of which ways they learn best and which ways they can learn stuff best.

I: Did you feel that was something that happened at River Falls, or was that something—
(R: Oh yeah, definitely.).

R: I think that was one thing that I thought [the instructor] did really well. He was able to sit down and take a difficult concept and show different people different ways to solve the concept based on—He got to know us really well.

I: Okay great. So when you're teaching a lesson, say that involves an equation, do you introduce all the variables at them at once, or do you do it gradually, starting out with, say, a stripped down version of the problem and then piling on a little—Do you pile it on in layers, or do you throw it all at them at once?

R: Oh, we try to layer stuff as much as possible. I think that if you get all of the big stuff thrown at you all at the same time, you might be able to muddle your way through it and be able to come up with an answer for it, but you don't really have an understanding of all of the underlying concepts that are there. I think if you break things down and go over things individually, then you can start to apply those to harder and harder problems, but I think if you do the really really tough stuff right at first, you don't really have an understanding of what you're doing.

I: Okay, and when you're presenting this material, there's lots of different ways to do it; we have graphs, we have tables, we have equations, we have words... do you use all of them, or is there a specific vehicle you use more often, or do you tend to use all of them in your presentations?

R: I try to use as many of them as possible. Everybody has a different learning style. Some people are visual, some people are all numbers, some people have to do different ways of learning the material, so the more ways you can present material and the more ways you can present problems, the better off the students are going to be.

I: All right. When you do that, when you go from one type to another like for instance in the Modeling curriculum especially, going from a graph to an equation, and then from an equation to a sentence... When you do that with the kids, do you assume they know how to do the translation, or do you think the translation is kind of an essential thing that you're responsible for teaching them?

R: Oh, I've found that I have to teach students the translation (Emphatic). I had to be taught the translation. I mean, when we first started the program, I could solve an equation. You could give me an equation, and I could look at a graph and understand the graph, but I didn't really understand how the two of those things actually related to one another and for students, that's one of the things that I find they really struggle with is the relationship between an equation and a graph, and what the variables mean, and what the different parts of an equation stand for... That's something we spend an awful lot of time on, and I think by the end, students get a better grasp of it, but that's something that's pretty tough for them.

I: So the process of translation between variables is one of the mountains we have to climb when we're teaching high school physics (R: I think so) in your mind?

R: Yeah, in my mind, definitely.

I: When you were in your undergraduate program, did they spend a lot of time teaching you how to translate from one form of data to another?

R: No. No, it was—the data was just there to put into an equation, and solve a problem. It was effective that way, but it didn't really lead to an understanding of how all the variables related to one another.

I: But with River Falls?

R: Oh, it gave me a much better understanding of that.

I: Did you feel they stressed translation more?

R: Oh yeah. River Falls stressed translation a ton (Emphatic). And there are times where—I wouldn't say they've gone too far, but I think there are times where we do a lab and I go back to how we did it at River Falls, and the translation from the graph, and the students will tell me "I can solve it this way, why would I have to do a graph?" And you're right, you don't have to do a graph, but for a lot of people it helps to be able to figure out the relationships between all those different variables. And I think for most people it's really helpful, but some people are numerical, and some people I don't think need that—we still do it, but everybody learns differently.

I: Okay, great. When you actually do a lab—I use the word lab, it could be some other kind of investigation with your kids, how do you typically begin an investigation? And when I use that term, I'm thinking of a lab, but I guess it could be a project as well.

R: Most of the time, it's usually—okay, so here's the question or here's the problem, and this is what we're trying to get at. And now, what do you guys think about—what are

some possible ways that we can solve this problem? And the kids sit down and brainstorm a little bit about some of the different things they can do, and we have the kids talk to each other, and then a lot of times they come up with ways they are going to solve it, sit down—Usually I have several different times throughout the activity or lab where they have to – before they go on to the next part, they have to sit down and talk to me so we can talk about things and see if there are issues they hadn't thought about. And then they can get some time and sit down and actually take the data that they need to, and solve the problem in a way that they see fit.

I: Do you give them a ton of information at the outset? How much information do you give them prior to them actually gathering data?

R: Usually the information that we get is—I will give them things that I think are necessary for them to solve the problem that they may not—most likely would not be able to come up with on their own, but other than that, I try to really leave it up to them to come up with different ways of solving it. Because, like I have said before I've found so many different ways of solving problems and carrying out investigations that I would have never thought about before.

I: Just by giving them the opportunity to—

R: Just by giving them the opportunity to do it, yeah.

I: Do your students pick their own lab groups, or do you assign their lab groups?

R: Most of the time, they pick their own. There are different times where I do assign lab groups—my physics students are usually all juniors and seniors in high school and are fairly mature, and will work well together. My ninth grade classes I usually go ahead and set up the lab groups for that because I find that there are always students that are being left out and there are always students that are screwing around a lot more. We have a broader range of students whereas my physics classes, all of the students can pretty much work with each other and be successful.

I: Are they always in the same groups?

R: No, they switch around.

I: You actually kind of answered my next one, about whether or not the investigation procedures are spelled out. It sounds like you give them—if I'm hearing you right—you give them a general problem but you give them a lot of latitude initially in how they are going to think about how to solve it?

R: Sure. One of the things I like to do with the lab activity is I like it to be kind of a—at the end of the unit where students can show me and show each other that they have an

understanding and a grasp of the material that we have learned about and they can relate concepts to one another so a lot of times, we'll do a certain type of activity where they have to use many different concepts we've learned to put those together to actually solve the problem.

I: Okay, and you kind of leave it open ended at the beginning? Do you have to actually have to tighten it up before they go into the lab, or is it possible that 4 or 5 groups might be doing 4 or 5 radically different things, even though they're all doing the same experiment?

R: I've had people doing radically different things to come up with an answer to a problem, but they've all sat down and gone over their tactics with me before they actually carry it out in the end because we're dealing with a limited amount of time, and I would like to just give everybody labs where you just go at it and report back to me when you get done, but if a student is heading down a totally wrong path, and you know they're heading down a totally wrong path, you don't have to say "You're wrong, it's not going to succeed," you can ask pointed questions that get the student to realize that "Oh, this isn't going to answer that, I'm going to have to go back and figure something out again."

I: So, along those same lines, while the students are investigating, gathering their data... what have you—what's your role? How do you interact with them while that's going on?

R: Well, my first role is to make sure that everyone is safe and not doing anything that could harm [themselves] or anybody else, that's role number one. Role number two is to ask questions that get students to think about what they're doing, help me figure out whether they're understanding the concepts, that are going on. Then, when students are getting stuck, I don't give them answers, but I can give students questions that can point them in certain directions that can give them things to think about.

I: Do you tend to intentionally try to do that? In other words, when they ask a question and they're looking for the answer, do you find it's your role more to set them up with another question so that they can come up with the answer?

R: Yeah. One of the things that some of my students—it's frustrating—that sometimes I get "Well, you're the teacher, give me the answer" (Laughter). Well, I don't see it as my job to give them the answers. I see it as my job to teach them how to find the answers. You know, because that's something that's going to carry them through the rest of their lives. If they can learn problem solving skills, and learn how to find the answers, that's definitely better for them than just "Okay, I answered that question, now let's go on to the next one."

I: Do you find that throws them off balance a little at first?

R: Sometimes, oh yeah first, it's difficult (Emphatic). It's a process. You can't just leave your students at the first day of the year and just let them kind of flounder on their own. It's something you have to work towards. It's a process.

I: Okay. So when the students finish, how do you typically have them present their lab findings?

R: Most of the time, it's through some type of lab write up—whether it be a formal lab write up like the kind we did at UWRF, which I thought was extremely valuable in understanding the materials. But sometimes, with time constraints the way they are, it's a stripped down version of that where they present me with their questions, any relevant data that they've taken, and any calculations and something like that. Most of the time they have to show that type of stuff, but sometimes it's more formal, sometimes it's even just... give me an answer back in five or ten minutes and we'll talk about the answers.

I: Okay, do you ever have them do it orally?

R: Yes, yup. We do many different things, we do whiteboards, we do actual lab write-ups, we do where we even just sometimes sit down and talk about what we learned about, and there's nothing that they have to turn in, we can just go over different things and they can kind of talk with each other about what they found out.

I: So sometimes there's a formal grade given where you go through with the red pen, and sometimes it's just [where] you listen to what they have to say and make a determination kind of on the fly?

R: Um hmm.

I: Okay. Do you favor one more than the other? Is there one method you favor more than the other?

R: No, I like to vary things as much as possible. I think if you do the same thing time in and time out—students aren't dumb, they know how to play the game for a teacher that just does one thing—is a one trick pony, and they basically learn the game. They don't learn what they are there to learn.

I: How much do labs count for in your class?

R: Labs count for about one quarter of my total grade in my class. I try to split up the grade between participation, lab grade, problem set grade, and tests and quizzes.

I: And what's the split between those four? You said 25 [%] for the lab—

R: It's about—the tests and quizzes are a little bit more than the problem sets, but it's generally all about in that $\frac{1}{4}$ to $\frac{1}{3}$ area.

I: All right, so about a quarter across the board for each one—pretty close?

R: Pretty close.

I: Okay, so what about your classroom space that you have available, is it adequate for the students you have—equipment, other resources?

R: Yeah, actually, it's a lot better than it was in the past. We remodeled the school, and we got some really nice lab areas. We have one big room, we have tables in one part, and we have a lab area in the other part. So we did quite a bit of renovating in that area.

I: How big are your classes typically—your physics classes?

R: My physics classes tend to be smaller. We are dealing with some issues being a small school district to start with, and—

I: How big are you?

R: This last year, I think we were at 360-370 total in the high school.

I: 9-12?

R: 9-12. And that's including our two alternative schools. So in actual students that we see, probably around 320 that we see. That's one of the issues that we're dealing with. Another issue that we're dealing with is that we are on block schedule which I think is great for learning physics and for learning science but it makes it really difficult for students to schedule their courses, especially if they're a music student.

I: You're opposite music?

R: No, we're not opposite music, but if the student is a music student, then basically they have three classes they can pick from. And a lot of times it's really difficult. We get put opposite of things like pre calc, and we're basically trying to go after a lot of the same students, and it's fairly difficult. If students are trying to follow through the track where they're trying to take advanced placement classes, they are much more limited in what exactly they can do.

I: Okay. Do you feel that you have adequate equipment for the classes that you have—adequate equipment, adequate space?

R: Equipment wise, everybody could always use more (I: Sure) definitely. But I figure for learning the concepts that we're learning, I think that what we have is adequate. We're always trying to push things and to get more things but I would say it's—adequate is a general term for—well, it's—I would say we have the minimal amount of equipment that we need to do what we do. It's not a comfortable amount of equipment where every student gets their own LabPro, or –

I: What is the ratio? How many students per LabPro or lab station?

R: Usually, it's between—depending on what lab we're doing, because some of the probes we use with LabPro are way more expensive, and we end up with four or five students together trying to do something with one LabPro, and sometimes, we have one LabPro for two students, which works out really well.

I: And how big are your classes for physics?

R: I would say average class for physics is probably 15-16 kids. I have taught physics with as few as ten kids, and with as many as 28 kids. They really vary each and every year.

I: Okay. And how many sections do you have?

R: We have one section.

I: One section of general. And you also have AP right?

R: The AP class is still on the books, but we have to have ten students to hold a class, and in the last couple of years we have not had enough students to hold that class.

I: Alright, so I guess just kind of wrapping things up here a little bit—the last thing a teacher has to do is they have to assess what their students do (R: Yes). You've actually kind of hit some of these already, but formative assessment that you use while your students are still investigating a topic—you've mentioned a few of them—what exactly do you do formatively then to make sure they are getting out of it what you expect them to?

R: We do lab reports. That's one of the things I can take a look at and know if the students understand what we are talking about. I try to have a lot of short quizzes that students can sit down, and in five minutes they can work out answers to a couple of different problems show that they understand a concept. A lot of times, it's just by sitting down and talking with the students and seeing what they know and what they don't know. Students are really good at saying “I don't understand what's going on here” and then we can kind of shift gears change what we are looking at a lot more.

I: Do you feel that every assessment has to be a graded one?

R: No. No, a lot of assessments I do aren't graded assessments. They're just—do we understand what's going on? I even have—I don't do this all the time, but there's different times where we have un-graded quizzes. It's just "okay, sit down, there's a quiz... let's take the quiz, it's not going to be for a grade, it's just going to be to see what you understand."

I: Do you feel the kids take that seriously?

R: Yeah (excitedly). At first, I didn't think they would, at first, I thought they would just blow it off, but there are a lot of times where you can tell a kid this isn't going to be for a grade, and they still take it seriously and just really want to learn the material. Now, that doesn't happen all of the time, but it happens a lot more than I thought it would.

I: Excellent. Do you find—or do you adapt assessments in different ways for different learners? When you are assessing knowledge, do you adapt assessments for different learning styles—different learning levels—maybe those are two separate questions?

R: With the tests I put together, I try to—I don't address each one of the students individually, but I try to put questions together and problems together that I think look at things from as many different aspects as possible so students can show that they understand things from as many different ways as possible. So, in that way, it kind of gives each one of the students an opportunity to answer stuff in their own way. And I think the answering five out of the seven questions kind of addresses that as well because some students are stronger in one area than another area [and] they can pick-pocket the question that they're strong in.

I: Okay. Do you ever give them like—let's say a student comes up to you and says "Instead of doing a written test, can I do a project?" or "Can I do an essay or something?" Have you ever run into that?

R: I haven't really ever had any students that have asked me to do that. That would be something that I would have to sit down and I would have to think about. I wouldn't—I'm not opposed to a student doing that, but it really depends on what we're trying to get out of that particular assessment or that particular test. I don't think I would be comfortable with having a physics student that wanted to write a poem about every single thing that we did, and that was his or her assessment for every single thing all semester.

I: It would be an interesting book of poetry, wouldn't it (Laughter). So it's June now, it's the end of the year. What do you hope to accomplish with your students when it's June—What are you hoping they get out of the time they spent with you in physics?

R: I'm hoping a lot of different things. I'm hoping that they learn physics concepts that are important physics concepts for life. I'm hoping that they become better problem solvers. I'm hoping that they become better at communicating with one another and with other people... me included. I'm hoping that they learn to become team members and to see each other's strengths. There are a lot of different goals that I actually set for my students at the beginning of the year and we try to see if we can reach those goals throughout the year (Loud chatter in background).

I: Do they know them?

R: Yes. And it's actually posted on our website... the goals for the course.

I: And at the end of the year, you look back on those goals and do you sit down with each student and go over it?

R: I don't go over it with each student. That's probably one of the things I should do but I don't do.

I: Take each one of them and figure out if they met them?

R: Yes.

I: I guess you kind of already answered that. How do you know when they've reached that goal? When you are looking at a student at the end of the year, what are some telltale signs that yes, they got it, or no, they didn't?

R: Well, I think you kind of have an idea just by getting to know the students, being involved with what they are doing, and if you're there as more of a facilitator just to help the students through what's going on, you have a much better idea than if you're just presenting the material and then they spit it back at you on the test. If you're there during the labs and all of the activities, and you're there to help the students through, you're going to know what they know and what they don't know a lot more than if you just lecture and that's it.

I: Just grade a test.

R: Yeah.

I: So what importance do you place on, say, standardized test scores—strictly summative kinds of things? In the overall scheme of things—purely an opinion question.

R: That's something I struggle with a lot. I know that some students are just really good test takers and they're going to do really good on those tests, and other students aren't and they're not able to show that they actually understand the material where they could

show it in a different way. And, I understand their importance with being able to place students in colleges, but I think we need to look at a lot of different things rather than just an ACT or an SAT score.

I: So kind of make those a part of the overall evaluation—

R: I would say it has its place. Definitely. I don't think we need to get rid of all that stuff, but I would like to see them be fair to all the students, and really make sure that the tests are assessing what they are trying to assess.

I: Okay excellent. So is there anything more you would like to say about your experiences at UWRF in the program?

R: I just have to say that my time there was invaluable as far as what I've learned and what I've been able to help my students with now. I think that without having gone through the program, I think I still would have grown as a teacher, but I don't think my students would have the experience that they have now. I'm not saying that it's the best experience in the world or that I'm the best teacher in the world, but I think I'm a lot better than where I was when I started, I can tell you that.

I: Okay. And is there anything more—I guess you kind of said this already too, but is there anything more you'd like to say about your knowledge and your experiences as a physics teacher?

R: I think a program like the UWRF program is extremely valuable. I would like to see that particular program actually be part of an undergraduate physics training program. I think that if you're going to teach physics, and you know you're going to teach physics in school, that would be the thing you should have before you actually hit the classroom and are able to understand a lot more things. Like I look back at my first year teaching physics, and I've talked to some of my students before, and I've had to tell them "I'm sorry." (Laughter) "I'm sorry you had to put up with me for a year."

I: They're pretty forgiving though (R: Yeah) (Laughter).

I: well, I certainly appreciate your insight. You gave me a lot of valuable information, and I appreciate you taking the time to talk to me today.

R: No problem.

Interview 8/3/2010

Gary

I: Alright, it's August 3rd, and I'm talking with [Gary] a teacher from [a city in] Wisconsin, right?

R: That's right, [---] High School.

I: And he's somebody that went through the program—Did you get your MSE or MST through the program Greg, I can't remember.

R: Yes I did.

I: Okay, what year did you finish?

R: I was afraid you'd ask that (Laughter)—

I: You don't have to answer that. That's more for me, I'm just curious.

R: 2004.

I: Okay, I guess I'll just go ahead and start with my first question then. The first question I've got for you—the first several—just kind of focus on your background and I'll ask [you] have you always taught physics from the time your career began?

R: No, I started with life science, biology, and physical science.

I: Life science, biology, and physical science. And how many years did you do that?

R: I had three years of life science, two years of biology, and these were half one and half the other during the course of the year, and I started teaching physical science my third year. I taught biology two years, then that got replaced with physical science. And I kept life science for five years I guess it was (he was surprised at how long he had done this when he answered this question). And then after that, it was continuous physical science 100% up until... oh boy... about eight years ago.

I: And then at what point did physics become part of your schedule?

R: Let's see, I've got to remember this now... it was the fall of 2001 I began teaching physics. I think I was certified before that, but 2001, yeah.

I: So how many years did you have in as an educator before you started teaching physics?

R: I started in '86, so fifteen years.

I: Fifteen years before you actually started teaching physics?

R: Yup.

I: Okay. What influences led to you wanting to teach physics, or was it something that you wanted to do, or something that your administration wanted you to do? What led you to it?

R: I guess mostly I was self- motivated. In short, I took a class at River Falls, just to get—keep up my certification in broad field science, and I found out it was part of a three year sequence so I decided to take all three years, and I realized I was close to being certified in physics. And that, combined with the idea that the present physics teacher was going to be retiring within two or three years—I knew they would be looking for a physics teacher, and I also knew they had either one or two sections a year that they taught, that I should be able to step into it because it would be hard to find a physics teacher—they want to teach full time, and there was no full time physics here. Kind of my idea and supported by administration afterwards.

I: Okay, great. Now, when you wandered in to start teaching physics, how well prepared did you feel initially? You know as that first year was just beginning, initially, how well prepared did you feel?

R: As far as basic content, and labs that could be used, and experiences that I knew I could give the kids, I felt very confident. But I also knew, because I lacked the actual experience—these were the first non-freshmen I taught in twelve years—I knew there was a lack of experience in actually doing it, but that goes with any new change in teaching positions. So, I felt confident I could give them a good physics experience for a first year physics teacher.

I: How much experience did you have—well, lets start with undergraduate—how many undergraduate physics courses did you take not counting River-Falls—not counting the program that we were a part of. How many undergraduate physics courses had you taken prior to actually teaching physics?

R: Just the two outside of River Falls-- Your basic first semester non-calculus [based physics] and your second semester non-calculus [based physics].

I: All right. Do you think that the years that you spent teaching physical science helped boost your confidence for teaching the physics class?

R: Definitely. I was able to try out some things with my freshmen that I learned from River Falls, and just getting re-exposed to some of the content in greater depth or reviewing the content. And I was able to make those small mistakes with them or find out where things can go wrong and how you had to fix them, or how to interpret results, and that helped a lot.

I: How many years or classes did you have at River Falls prior to teaching your first physics class?

R: Hmmm. Hey, did we start together? Was that in '95?

I: If you started in '95, you were ahead of me. I started in '98, but I remember you were there.

R: Okay, so I started later then... I must have started in '97—Because—who were some of the people in the class?

I: Well, Scott Benzing started in '97 I think.

R: Scott. Yeah, okay.

I: Because he had been there a year before I got there.

R: Yeah, so I started in '97, and then if I started teaching in 2001, that gave me—like four years to kind of get myself ready I guess.

I: Do you feel that that helped you?

R: Oh, tremendously. First, the professional contacts, whether it's sharing the stories and experiences, or going through some of these same things at the same time, that—the support network was exceptional. The support of the professors when you got stuck on something—whether you were working on something at the course, or you in the middle of your teaching day and something was coming up, I knew that there was a good resource to tap into. The activities they exposed us to—in other words the labs they exposed us to, and how they evaluated them gave me some very good things to think about as far as how I wanted to approach the material for the kids—what were the other big things—oh yeah... the teaching techniques! That's where I was first exposed to Modeling which, you know pushed me as a student but really got me thinking as a teacher—you know the difference between being concerned about teaching the subject to kids as opposed to being concerned about having the kids learn—the Modeling made a huge impression on me. The resources from the demonstrations that were shared were a tremendous resource, and still are. Those things really stood out in my mind. But then later on I realized what needed to be done for the AP Physics level course—our school was considering—what they were trying to do was to get some AP courses generated, in

all of our subject areas. And this gave me some background where I felt qualified to comment on physics and how it could or could not work in our present system. So, those things really stood out in my mind as to the kind of experiences that helped me along over the years.

I: Okay, great. Now, you said that you had the non-calculus based sequence as an undergraduate at some point, and then later on you went on to take the classes through UW-River Falls—Is there—could you comment somehow on comparing the way that those courses in your undergraduate career were taught versus how the courses at River Falls were taught? Was there a difference in the focus, or in the method—does anything come to mind, or were they pretty much identical?

R: No, there was a significant difference. My undergraduate courses at [my undergraduate university] in a lecture hall with hundreds of students—and then of course there were the lab sections—I would say it was more of the traditional lecture and lab sequence. And during the labs, you read the book, you got the data, and you came up with, you know, the cookbook solution and explanation to what was going on. You were really kind of proving what was already known. And that's a very traditional way. And when I walked away from the [my undergraduate university], I felt I had a fairly good understanding, but I also knew I could have gotten deeper into it. It's not necessarily their fault, but I—my age too, I was in my early twenties and it was a matter of just taking a course and getting a grade and moving on. Now, when I got to UW-River Falls, I guess I was almost expecting something similar to that, but because of the smaller numbers, and the focus of trying to get teachers certified, but also to help them understand the—truly understand the physics, I was able—with that kind of instruction—I was able to spend time to understand what was going on. And also they exposed the different ways of presenting the information based on—whether it was other techniques or other teachers experiences. You know the uh (struggling to remember the name) the PTRAs (I: Yup, the PTRAs) through the use of the PTRAs—I mean, you had three teachers with three different experiences and you could sit down with them and listen to those experiences and how to present material, how to evaluate it, how to—you know feedback to the kids. That's something that was not available to a typical undergraduate course, and the focus of River Falls was to get teachers certified as opposed to [my undergraduate university] undergrad was the purpose of exposing physics. Also, being older helped my focus too. I mean, I knew how this would relate to my job, so my motivation was definitely different. Regardless of what my motivation would have been, the way they presented the material and the activities, and the way they interacted with us as students really helped me understand things much better.

I: And now in teacher-speak, when you say “the way that they presented the material,” in your own words, how could you explain maybe the way they presented, in your mind you could pick any topic that you want—that you went through—What specifically did they do different that stood out in your mind that maybe you didn't see in your undergraduate experience?

R: The first and foremost thing was the Modeling technique where students were able to—they would do a lab based on a simple demonstration while the students—okay, let me start from the beginning—The students were presented with a demonstration, and there was some general discussion. Sometimes there would be a discrepant event involved, or information—you might summarize from the demonstration that didn't seem to fit the model you had in your head, so then we as students would then perform the lab, gather data, and then through integrated technology which was another big thing I forgot to mention earlier—The exposure of Logger Pro—the software program—Actually at that time, what the heck was that called... the graphing program itself (I: Graphical Analysis?) Yeah, Graphical Analysis which eventually became Logger Pro—the use of graphing that data getting immediate feedback, and then coming up with a mathematical model impressed me—instead of being told about a law such as Newton's Second Law which everyone can recite mathematically if they know any basic science, and—you came up with it, and the experience of manipulating the data—it was almost like a sense of empowerment that you could go out and maybe try to find other relationships on your own if need be. But, it also showed that sometimes—and this impressed me—it showed me that sometimes you gathered the data, and you knew it was related to the law, but how you manipulated the data wasn't as simple as it might seem. For example, Newton's Second Law, I fully understood what inertia meant, and that you had to keep the total mass of the entire system constant, not just the cart that was moving and that was huge to me, because I never fully appreciated that that information was there (Emphatic). So that's kind of like the difference between a physical science lab for freshmen, and a true physics lab for say high school kids and college—

I: That you couldn't just keep adding mass to the system, you had to remove it from one part of the system and add it to another part?

R: Yeah, exactly. And that became important and so that caused me to reevaluate how do I see the world? How do I try to analyze the system? Is it—did I consider everything? And that's what I pass on to my students, and I think if nothing else, that process of gathering the data and trying to see the data in new light—forcing you to do it without saying “oh, by the way, this is the Law, let's make sure you get it for you lab”—I think that was the true science.

I: Well, one of the things you said actually reminded me of when it kind of started sinking with me. I think I heard you say about a few minutes ago that when you graphed the data, and out of the graph came the equation, that it got you thinking about “are there other things out there in nature that you could graph one against the other and come up with a new equation?” Was there a point in your training when all of a sudden, you just—you found yourself just randomly looking for things to graph, or thinking about “I wonder what a graph of that variable versus that variable would look like?” Was there a time when that light came on and you found yourself doing that?

R: Yeah. Remembering when that specific time was might be tough. I know it happened at home in the middle of the school year. After I had gotten done with Newton's Laws and we were coming into momentum, and I started considering "How do I see momentum? Can I graph something and come up with a relationship that would make sense that the kids could do, or whatever?" And offhand so I was teaching—it would have been right around a year or two after I started seeing—so let's say right around 2000-- Because I'd say two years after the fact. Because the first couple of years I was incorporating some of these new things—I was just trying to keep up with what I understood completely you know? (I: Sure) Things presented to me right then and there. But yeah, about two years later, I started looking at all the other possibilities and that's when I thought the physics really got fun.

I: Cool. Now, you had also mentioned Modeling, but can you comment at all maybe on specifically the attitude of the professors in one program versus another? Did you feel at all that maybe you were treated differently, or that the student body was treated differently in one program versus another—your undergraduate versus River Falls?

R: Sure. I kinda gotta answer this in two ways. At River Falls, since the professors were personally involved with a small number of students, they were able to interact more often-- And that in itself—that might cause a difference in—you know, my experiences. But getting back to answer your question, at [my undergraduate university] as an undergrad, the professor there with 500 students in the lecture hall—the professor had passion, he was entertaining, he was thorough—I mean, he was an excellent professor, he knew his stuff, but he had no contact with us. And he might use discrepant events to try to show some things, or just theatrical demonstrations, but the discussion was pretty much one-way. Then in lab, we had teaching assistants who obviously were not professors, they were graduate students, and they were always nice and helpful, but you kind of had to go to them. They were just kind of making sure the lab was working out right. So you could get the assignment right. Okay, the difference at River Falls regardless of who was in charge of the lab—they were interacting with the students as the students were interacting with the lab itself, and instead of giving us defined answers, they were kind of probing us—whether it was to test our understanding, to see how we were seeing the lab, or maybe they were asking us questions to—you know open ended questions to stimulate more thinking or stimulate a different perspective on the whole lab. You know that happened, obviously much more—there was still the traditional making sure the lab was going right as far as things were plugged in the right way and all that, but certainly there was this open ended component and probing kind of nature that felt like—yeah this science, this is research and you're not quite sure where you're going, but you got something in front of you, you've just got to figure out what it is.

I: Okay, excellent—excellent perspective. Is there anything else—well I guess you kind of hit on a couple of the questions I had lined up coming next, you did a real nice job of hitting just about each one of them. Is there anything else about the program in particular

that I failed to mention that you think somebody reading a study about physics teacher training programs might want to know about?

R: (Long pause) Let's see, I'm trying to cover something maybe I haven't covered before. The support network is huge to me. Maybe I don't use it as often as I could, but I know it's there, and—

I: What do you mean by “support network?”

R: Okay, fellow teachers who were students at UW-River Falls—we have ways of contacting them—you know—assuming it's within a couple years of that class that's how I think, because we would try each other's demonstrations, and they wouldn't quite work, and, you know, you could contact them and yeah... “Hey, how does this work? Oh yeah you know you're supposed to do this and all of a sudden—yeah, I see what's going on. Thanks.” Because there's a lot of times you are trying to get something done and whatever instruction manual you might get, it just doesn't work.

I: When you say “each other's demonstrations,” was there a specific time or day or something where the students were required to do something like a demonstration?

R: That's right, yeah... Every class there that I've taken in physics they have a physics sharing session toward the end of the—you know the end of the session—if it's a one week course, you're talking either late Thursday or early Friday—it would always appear at the end of the course no matter how long the course was, and it was a chance to see the demonstrations enacted, it was a chance to ask questions about it, discuss applications, you know when to use it, whether you brought your own in because you kind of knew what was expected, or you showed up and didn't read the fine print, the resource materials were there, you had support from the teaching staff—the faculty there at River Falls to help put it together, and between that, and [inaudible] instead of a packet of papers, they're on DVD or CD-ROM and you could take that with you. Yeah, no matter how good your notes are, there's nothing like seeing the original worksheet that was handed out and having a sort of collection— and I believe they do this now for the whole summer-- all the courses put together which is kind of neat (I: I think you're right) and you've got this resource. That helped a lot. That's something specifically of teacher training-- it's huge as opposed to taking a basic curriculum and instruction course on science methods—you know—thinking back to when I was twenty-something and we had to perform some sort of presentation, for our fellow classmates, back at [my undergraduate university], sometimes you just kind of winged through it because you were assigned the demonstration and—that's what happened to me, I got assigned a demonstration and it's like “okay, I'll try to make this work for the class”, and you sit there and listen to everybody else's and you know, I don't remember a single thing about that, but when you're in a physics sharing session, and you have a chance to sit down and discuss experiences behind it —man! If you're going to become a physics teacher, that was the way to go—as far as getting that kind of information.

I: So you felt that maybe that the River Falls program seemed to target specific needs of teachers more so than your undergraduate program that you had seen before?

R: Oh definitely. You know, [my undergraduate university] is looked upon as a leader in education research. But when I took the classes through them, it was just another set of classes. When I went to UW-River Falls, There was a real concerted, coordinated effort to make us better science teachers. It improved me throughout—I mean everything else I taught—it opened up a whole new perspective to—instead of talking about the research, we were living it. We were immersed in it. And we got to see the good, the bad, and the ugly of whatever technique, or whatever demonstration, or—you know—whatever it was we were right in the middle of it.

I: Did you feel that the River Falls program was more competitive or collaborative in nature?

R: Oh, definitely collaborative. Again, it had to do with the sharing. When there was the physics sharing, the PTRAs, the professors, or just sitting there next to your fellow peers—you know—we already had our jobs, you know—we were sharing the battle stories, successes—whatever.

I: You almost make it sound like a family setting.

R: Oh, definitely. Well when you get stuck in a dorm for three weeks and there's a core of us, and you do that for three years in a row (Laughter) you're going to be family—hopefully you all get along. And in [my undergraduate university], I lived at home, so I didn't get the dorm life. So my dorm life experience is based on UW-River Falls and I was in my late thirties--early forties—whatever. What a different perspective! It probably helped a lot. (Laughter).

I: Did you take part in the problem solving sessions they had in the evening there?

R: Oh, God, the first two years, I lived in there! (Lots of laughter)

I: Yeah, I think I remember seeing you in there—I did too.

R: It was in that first year—I started with Modern that first year and my head was spinning, I was going “what the hell did I get myself into?”

I: Modern was your first core course?

R: Yeah, and there was a lot of pity for those of us who started with Modern.

I: Mine was too, so you must have started in '98.

R: Was it '98?

I: Yeah.

R: Okay, yeah. Oh! That's right. Weren't you the guy that was on the levitation--?

I: What's that?

R: During the physics sharing session, weren't you the guy that was being levitated?

I: Yeah, I had really long hair (Lots of laughter) I used to have really long hair.

R: You were the sucker! All right. (Laughter)

I: Yeah, that was me. I got volunteered for that. (Laughter) Oh, cool.

R: Sure, so that was '98. All right-okay.

I: I started in '98 and I finished in 2000. But I was single then—and I just wanted to get through and get done, and with Scott Benzing's help, I was able to do that.

I: So would you say then—going into your classroom—Do you feel that the way that you lecture to your students has changed as a result of what you saw at River Falls?

R: Definitely, because I don't lecture. You know—the big difference—at UW Madison there was lecturing, and certainly at River Falls there was lecturing, and I will explain. There are times when you have to lead a group discussion and summarize what's going on, and that's where I place my lecture—it's not at the beginning, it's at the end. So what little lecturing I do, that's where it happens.

I: So it tends to come in more at the end of a lesson?

R: Yup.

I: Okay, I'm going to ask a question or two about that here shortly, because that's an interesting point that you brought up. When I talk about the way you specifically structure a lesson, do you have—do your students do a lot of work individually, or do you tend to focus more on group activities?

R: I'd say it's more group activities. I want them collaborating. I want them sharing ideas, no matter how they feel about them. I want them talking. To me, if the room isn't noisy, then they are deeply confused (laughter). And when the time comes and they leave the classroom, it's up to them if they want to get together. Otherwise, it's a pretty

individual base of course. I guess it depends on their personal schedule and their personal contacts.

I: So now the group activities—Is that a philosophy you’ve always carried with you, or is that something you picked up from the program?

R: No, that’s something I’ve always carried with me. I always figured that you need at least one partner whether it’s setting up materials, or “did you maybe see that,” or you know, to get that immediate feedback. But in groups of four—I often have groups of four because there seems to be enough jobs—it helps when I say compact lab (?) One person is on computer entering data, another person is reading the clock, another person is setting things up and resetting it. You know, this divide and conquer helps speed things up, because that time you have in class is precious—there’s too little time.

I: It goes fast.

R: Yeah, so groups of four is pretty standard.

I: How big are your classes typically?

R: A maximum of 24, and a minimum of—I don’t think I’ve ever had fewer than sixteen in a class.

I: Does your district hold strict to that 24 student maximum?

R: So far, yes.

I: Count yourself lucky.

R: Yes. We have really held the line on it, and so far, we’re hanging on to ‘er. Because one thing that helps is we say “look at the room, how can you fit in more desks?” Because we have the lab space, and we have these desks, and if they go back in lab, we start talking about safety and liability issues so—And like this research base—I don’t know if the research is out there, but we just tell them “We’re not going to get to all these kids if you put more than 24, 24 is tough enough.

I: Well, I’m doing my part (laughter). So do you feel like the level of the homework that you give your students-- has—did River Falls cause that to change at all, or has that pretty much stayed constant throughout?

R: That’s changed. I feel as though when they get towards the end of a unit and we start addressing problems to solve, the typical story problems, I don’t have to worry about picking and choosing ones I feel they can handle, I feel like I’m trying to pick a more diverse set of problems to challenge them, to apply all they have learned, and I was very

satisfied with that. So it has allowed me to give them more diverse problem sets instead of a narrow sampling.

I: And do you feel that that's because that's prepared you better? You were able—you have a bigger picture of how things tie together?

R: Yeah. Going back to the Modeling technique where they generate the graphs, I'm able to show them—by using a graph, and then the resulting equation, I'm able to show them that as long as you have these variables addressed, there ought to be a way to solve the problem. And we're talking about complex problems where for example—a train leaves Pittsburgh at 2:00 AM and three hours later the other train leaves Philadelphia, and they're both heading to San Francisco—you know—where are they going to meet—where are they going to intersect—kind of thing—Those kind of problems are easy to solve because they've been given the kind of tools to handle a complex problem as opposed to trying to memorize one equation, hoping it fits.

I: Great. So, very closely related to that then, when you assess students—has how you assess students changed as a result of what you were exposed to in the River Falls program?

R: One direct change I made was offering a test where the students can pick the problems. But I do design it in such a way that they have to address the objectives covered in one part of the test or the other, all right? So one example is if for some reason giving them a small test, they have to get 40 points on it—there might be four 10-point questions on it, two 20-point questions and a 40-point question. And they can pick and choose two 10-point questions and a 20-point question in such a way that they're going to cover all of the objectives, or they could pick the 40-point question, which somehow covers it all. That part of it, I got from River Fall—so that there's a little bit more ownership of the students towards their success and achievement. They're in a comfort zone, hoping they can find a way to demonstrate their mastery of the objectives that way. But I will say there are some changes coming up with the AP that I need to take a look at some more diverse test strategies as far as what I need to offer them, and then how they need to solve problems in preparation for the AP test format.

I: I hate to say this, but I taught AP Physics-B for four years in New Berlin, and I found that I had to revert back to being very, very traditional simply because I had a test I had to prepare them for that was very, very traditional.

R: Okay. Yup.

I: I mean, you might find a creative way around it, I only did it for four years, so I was never able to find my way around that.

R: I think what I'm looking at—I have an opportunity here—we have a schedule called Section-14. If you saw this in the schedule, it would look like a college schedule, okay? So that we meet for lab an hour and a half, two days a week, and then a one hour discussion on a third day. And, if you take the AP though, this is new—we're going to meet for an additional hour for a forth day. And during that time, that's where I'm going to play around with the one minute questions, or try to show your understanding of—say this motion or changing motion—a couple of different ways. You know, really stretch their horizons on how to handle the test. Right now, I know the short story-type problems—that part of the test—I know they can handle themselves well on that, but it's the—get to the point and answer it—kind of stuff—they're going to need a bit more practice—I haven't done much with that.

I: Certainly. And you'll find your way as you go through it. So—you mentioned a few—but just kind of in summary—What aspects from the UWRF program have you found ready-made, and really easy to transfer over into your own curriculum and your own classroom?

R: Okay. The physics sharing is the first thing—the sharing and demonstrations and the cataloguing thereof stands out. The labs they presented to us, I felt that most of them were able to be done in a high school physics setting. There were a couple that we wouldn't be able to afford (laughter)—like the Helmholtz coil (more laughter). Let's see. The exposure to the Modeling technique—I think I'm still answering your question—(I: You are--) Okay, yeah. Exposure to the Modeling technique—that was—played a huge role.

I: And you mentioned the way you structure your homework and assessments as well.

R: Oh yeah, yeah, yeah-- Definitely yeah. Based on other teachers' experiences, both faculty and my peers, yeah.

I: Was there anything that you saw that you'd love to implement into your classroom but you haven't been able to?

R: (Long pause) Boy, I'm not coming up with anything. I think all the neat toys I saw—and by toys, I mean activities—I've been able to do—that I felt were like—yeah, I can make this work. Especially when you take a look at a lab and you have some hesitation about it—you know those are the boys—you know? Whether it's lack of confidence—like the Helmholtz coil you know? Can I justify that expense and those other things? No, I can't, and I'm not going to worry about it. And to be honest with you, we don't teach E&M, because it's—we're devoted to—basically first semester physics, you know?

I: Sure. So is there anything that you feel like, that you use that you think is really important that River Falls never brought up? I mean things that were born of you, and weren't part of the program?

R: (Long pause) Alright, um, the only reason I can think of this is because the idea was introduced to me after I was done at River Falls, and so therefore, it might not have been a hot topic, so I'd say to a degree—differentiation.

I: Explain that.

R: Okay. The one thing—okay—differentiation—addressing students at their appropriate levels so they can achieve personal success. Addressing their learning style—their learning techniques (loud feedback though the recording device). Now, the one thing they did do—they did talk about—AP calculus—calculus based physics and non-calculus based physics—They always addressed the non-calculus based-algebra based—that was their foundation. They would refer to calculus based—that was the only differentiation they did. And at the time, you know, that seemed appropriate to me. I understood what they were trying to do, and all the things they were trying to do. In the last five to seven years, there's been a big push for differentiation, as far as having students demonstrate the different ways they would learn and understand. Now, when I think about this, I have to backtrack a little bit. The Modeling was—it wasn't explained to us this way—not up to our face—you know slamming me right in the forehead—it just did now, though—The Modeling allowed differentiation to happen. As students were describing what was happening in their terms in the lab—Now everybody had a similar—not exactly the same, but a similar lab experience when we went through Modeling, but it did allow students to see things differently to a point. They could describe things in a way, you know, they could come up with their own relationships and that's differentiation (beep on the telephone). My immediate concern when I think of differentiation though, is we just got done discussing this with a group of science teachers (beep on the telephone) that's why I'm here at 3:10, we were done at 3, is, when we're giving formative assessments, we're trying to scaffold the assignments a little bit for some of our assignments—An upper level student doesn't have to do the basic terms and definitions that they already know, or that they feel they already understand. They're addressing higher level thinking skills on Bloom's taxonomy. So in a nutshell, that's one thing we're addressing now. I don't know if River Falls addressed it so much, but the foundation was there based on Modeling techniques, and whatever calc-based or non-calc based—I mean—elements of that were already there. It just wasn't an emphasis as much as it is now in our district.

I: Okay, and probably in education as a whole.

R: Yeah, exactly. Exactly. And I don't see it as a deficiency on their part, because nobody knew that that was much of a need anywhere in education.

I: Right. So now, by talking about focusing on Modeling, you've kind of given me some ideas about what you're going to say here, but I'm just going to double check. (R: Sure).

When you're—in your mind right now, pick a new topic—imagine it's a day where you're going to start a brand new topic—How do you initially engage your students?

R: I would start with a demonstration. And that demonstration would be probably something—almost always would have some measured data involved—but not a lot. And from that point, at least they know how to set up the basic lab, which is important. But then, trying to bring up a question to them that would cause them to predict an outcome that's outside of what they've observed. And certainly there'd be some demonstration—some discussion amongst all the students—you know—whether they would agree or disagree with each other, or there's other possibilities to consider, they might even ask a what if, meaning, what if we change the nature of the experiment, and what that does is—if they've seen what the setup is like, then there's a little bit of paperwork background, some things to record as you're doing this, basic kind of technological instruction—okay, how to get the numbers, also some discussion on what's your dependent and independent variable—making sure you narrow that down. Then, they are released into the lab, and that's where I just sort of start monitoring and making sure the setups are basically right, asking them about their data. I'm basically repeating what I've seen done for me when I was a student. The setups are set up in such a way that they're getting data that at least makes sense as far as being able to make it into a graph, and that there's no boogey-men hiding inside the equipment (laughter) or something like that. So, once they collect their data and they have it graphed, then, they are to come up with some sort of mathematical relationship, and then they will grab the white boards—which is something that I haven't really talked about—but now that's the main thing getting back to the class—and before they present to the class, I'm going to scan over the white boards, and there are expectations—that each white board has to communicate certain things in certain ways—so that we're still talking about certain variables, and so on—just to help the discussion along. And then I'll usually start with a whiteboard that is fairly basic and simple—perhaps not as deep as some other whiteboards—Some whiteboards—they get into great depth about the data they generated, and the relationships that have come about and the mathematical equations—I try to save them for last, and somewhere in the middle, you might get some questionable ones that perhaps are not complete, or perhaps they're wrong, or it's confusing because they've misinterpreted something, and they graph it in such a way that it's not clear to the rest of the students—not necessarily wrong, it might open up some other discussion out there, but anyhow, through the course of those discussions, hopefully students are keeping a journal of new thoughts, new ideas, and the discussions then become their notes, or questions they need to write down to ask later for clarification in case—if it's past the point of discussion. But anyhow, once we get to that point, then as we start closing discussion, then I will be nudging the students towards an overall summary—seeing if they see—whether it's Newton's Second Law, or a conservation of momentum equation or whatever—eventually we will get to what many professors or teachers will start with—a traditional lecture in where “Oh here is what Newton came up with,” and this is how it applies—see eventually we start working towards that. But there's also that possibility it could generate a second lab—whether it's a student doing it on the side, or

the whole class kind of working on something. It depends on where we're at. You know, you've got to get to some sort of closure at some point in time. You've just got to make sure they are heading the right direction.

I: So where in the process do you figure out what their prior knowledge is—what they've come to the table with before they met you?

R: I know I haven't done a good job on this. I know I give them the FCI at the beginning of the year, but the first few years, I forgot to give them the follow up at the end of the—(Laughter) – and stuff like that. And last year, I forgot to give it to them at the beginning, so that was kind of a bummer. But, the preconceived notions usually come up during my demonstrations. There's not one definite point. They come up anywhere from my demonstrations through the whiteboard presentations. That's when they say "Wait a second, I thought it should act like this"—which generates more discussion.

I: Do you specifically set labs up to create a misconception? I think you actually said this a few minutes ago—but I'm just making sure—do you specifically design a demonstration or a lab experience or something where in your mind you know ahead of time that what they are going to see is going to contradict what they think they're going to see?

R: Yeah. The one I can think of is uh—I'm forgetting the name of it—what kind of machine is that? It's uh, they got one single pulley, and you got one string connecting two weights, one on each side of the pulley—

I: Atwood's machine.

R: Atwood's machine. Thank you. Yeah that one, depending on our time, because we're trying to fit this in with WKCE exams for sophomores and Thanksgiving or—there's always something coming up. Either we do the lab for real or as a computer simulation, but they don't have a clue about how that's going to work. They think they know how it's going to work, but that's where we get to that real deep understanding of what inertia is—that it's the total mass of a system being accelerated, not just the one side. And because they will formulate a hypothesis—the one side, since it's a bigger mass—oh, that's my force applied, you know mass times gravity, and the other side—oh, that's the mass being accelerated—and then when they run the trial, it's nowhere near what they thought it was. And that's when the learning starts.

I: And so is it through classroom discussion where the variables tend to come up that you are going to test?

R: Yes.

I: Do you introduce them to them a little at a time, or do you throw all of them at them at once?

R: No, we will—when I do a demonstration, then we'll sit back and say "What are the possible variables?" And we just brainstorm at first, just to get stuff up there and generate discussion. And then we'll start narrowing it down as to what really is a variable and we have what is part of the control, and what is something we can possibly test in a cause and effect relationship. And sometimes we might have two or three different causes, and—yeah—all right, you compare this one as a cause, go ahead and work on it, you propose that—this group over here proposes that as a cause, you work on that. So, we're not all doing the same experiment at once sometimes. It's just—

I: So you have different groups doing different experiments kind of checking the same thing, but they're not all doing the same cookie cutter experiment?

R: Exactly, yup. If a teacher walks in from out of the blue and takes a look, they might see a similar set up—you know, the same technology being used—but they will see some subtle differences to them, but from the world of physics, some huge differences. And when we start comparing results, that's when we're going to figure out what the bottom line law is and what the relationship is then. Yup.

I: So how many different ways do you present material to them? Meaning graphs, data, equations, paragraph form, sentence form, do you kind of give them the whole thing, or are there certain things you tend to favor more than others?

R: I try to give them a wide variety. I'm trying to address their different learning styles, whether they're more mathematical, more verbal, and they tend to be more mathematical. And the graphical helps those who are a bit more visually inclined. Those two things stand out in my mind-- first of all, you know the words, terms, definitions, and very basic mathematical equation models. I mean, we get to that point where we are solving problems, and we have the kids who will use the graphs a lot, and then we have those who—I just need the equation—just let me play around with that equation—just give me the numbers and I'll start working stuff from there. And then I try to challenge them also that by trying to describe motion or change in motion in more than one way, to make sure they are not getting caught in a rut.

I: What do you mean by "In more than one way?"

R: For example, you could draw a graph—a distance versus time graph—draw a line on it and they could describe the motion that way. But then there's also the motion map where each dot represents a second. It looks almost like a number line, and that's another way to describe the change in position during an equal amount of time and it forces them to think things through a little different, especially when you get into accelerated motion. That really challenges some people including myself. (Laughter).

I: I hear you (more laughter).

R: I think it's important for them to try to describe these relationships in more than one way, because the research I understand says the more ways they can understand – on Gardner's multiple intelligences—the more ways they can understand it and communicate it, the deeper understanding they have, and the more chances they will get it right.

I: Okay, so when you're going from say a graph to an equation, or an equation to a definition, or what have you, do you find that the students can naturally translate from one form to the other, or do you find that that tends to be an area where they struggle?

R: I think that's where they struggle. And that's why we do that. That's why I do it that way. I want them to be able to walk into any problem and eventually, give themselves a method of solving it that they feel confident in, in coming up with a correct solution. But in order to do that, sometimes it seems easier to be more mathematical. Sometimes it seems that you have to be more graphical—it just seems easier to get to the right answer. And by practicing each way, I'm just giving them more tools to work with. And I've been very satisfied with that. I've had students come back—especially the last two or three years, and I've done a lot more of the graphical type stuff, and relating it to very basic calculus—they've come back from their college courses and they've said “Yeah, everything went fine... we felt well prepared” so—

I: Did you feel that's something that's River Falls stressed—the importance of the translation from one form of expression to another?

R: (Long pause) You know, when you say “stressed”, they made it so—yeah, you had to do it, and I guess that in itself is stressing it—I mean, I never felt like we were sat down and told “this was the way it has to be,” but the nature of their questioning when they were trying to get you to describe what was going on—that was stressed there—that was part of that immersion—this is just how things get done—can you show me graphically how that is? Because that will help me—you know the person posing the question—whether it was a peer or a professor—say “Yeah, help me understand this” well, okay, you know, because that's our job as teachers. It doesn't matter how much we understand it, it matters how much we can get them to understand it.

I: Did you feel in your undergraduate program that they felt that taking the time to teach you how to translate from one form of data expression to another was a high priority?

R: No-- Plain and simple, no. It was just a matter of “Can you take this equation and come up with the right answer?” And sometimes when you got to the complex problems like the two moving particles or bodies, when will they intersect? Up until I went to River Falls, I wasn't sure how to solve for those things, but as soon as I saw River

Falls—how Modeling and the professors at River Falls did some things—especially graphically—then it seemed simple.

I: So you felt that the River Falls program paid more attention to the art of translation as it were then maybe a typical undergraduate program?

R: Oh definitely (emphatic). It's funny you mention translation, because it seemed like at [my undergraduate university], we were taught at a very low level like memory translation—kind of—Bloom's taxonomy level-- Whereas at UW River Falls, you had a much higher level of interpretive analysis and application. It seemed like at [my undergraduate university], memorize this and use it to solve the problem was this huge leap. Whereas at River Falls in the Modeling technique, you worked your way through all these levels of comprehension, and it's kind of like an athlete, instead of just running and trying to get faster, you were lifting weights, stretching, and doing yoga, and then running, and running in different ways, and you—yeah—you've got a lot more tools to work with to get the job done—to solve the problem.

I: Okay. I asked about it because that's a major research—In the lit review that I've been working on, they talk a lot about the importance of teaching students how to translate from one form of data to another—and that it's not a given.

R: No, it's not! (Emphatic)

I: So when you have your students working, you said—if I heard you right—and you're following the Modeling curriculum—it's primarily a lab based curriculum then—would that be a fair statement?

R: Yes it is.

I: You kind of explained that your investigations begin with doing some sort of a demonstration and then talking about what they saw, and introducing possible variables—I heard that?

R: Yup.

I: Okay, when your students are actually in lab groups, do they pick their own lab groups, or do you pick them for them?

R: Um... a little bit of both with that. In the beginning of the year, I don't have a seating chart for my seniors. I tend to know who they are pretty much. And so, they kind of naturally clump together. So when they're in groups of three or four, they're probably sitting next to people they're familiar with. But then right around the quarter—then I start changing things around. But I'll say, "Look, sit with at least two other people you didn't sit with before." So, they're still picking their groups, but I get them mixed up so

by the end of the year, they should have worked with almost everybody in the room at one point or another.

I: Oh, good. When you start an investigation then, it sounded like you don't spell everything out in great detail. Is everything lock step for you, or do you kind of leave things a little more open-ended in how the students are going to set things up and how they're going to test one variable against another? Are you lock step, or are you a little bit more open-ended that way?

R: I would say I'm more open-ended because group one—they might have one set of masses that cause some sort of change, but group two might do something slightly different with the masses. And there might be two other groups doing the same thing as they are. Certainly if a student were to bring up a possible cause-effect relationship we hadn't discussed before, or I hadn't thought of—and I feel it has potential—it fits within the time and equipment limitations we have—you know, I would encourage them to pursue it then because in the end, even though you might have slightly different results—you know, one lab might not work—you don't want a whole class full of labs that didn't work—you know, coming up with no conclusion (I: Sure) So that's where—I know back when constructivist theory started happening, some people were so completely open ended, there was a lot of wasted time because there was no direction and now presently—I know the present Modeling technique—they're trying to—it's more like guided discovery if you're looking for a simple phrase—I hope that's the correct vernacular now in education—but I—(I: I've heard it called guided inquiry) Guided inquiry. Yeah, well, there you go—look at how old I am. Guided discovery was one of those old terms.

I: That's probably an alternate term for it.

R: Yup. So, there's more open-ended logic, but it's making sure they're heading in the right direction, so we can get to a logical summation.

I: So what's your role when they're taking their data, and they're in their groups and they're setting things up—what are you doing?

R: I'm checking out sports websites on the Internet—No! (Laughter) I almost said something else, but I know it's being recorded (more laughter) —(Interruption from summer custodian about the floors for 45 seconds)... No, okay, to answer your question—What am I doing? I'm first of all making sure that the basic setups are set up correctly. Again, you don't want them going down a dead end and getting bad results as a result of just bad technology. But, the next priority then is making sure they are getting the right kind of data as far as—are they recording it correctly? Are they reading it correctly? Are they resetting things up okay? And then the next thing—after that, I'll start probing—when they finally get some data, kind of making sure that yeah, they're on the right track and they are starting to make sense. Then I'll start asking them questions about—are you seeing the relationship? Is it a curve, is it a line, is it a positive or

negative direction, or inverse? You know, just little things to see where their heads are at. Then, sometimes, they'll bring up a question on their own and—you know—I'm not the store where they just ask a question and I give the answer and we're done. I want to make sure I give them just enough to keep them going—to make them think if that's a need in the appropriate situation. Obviously, if they're trying to read something, I'm trying to make sure that—yeah, this is how you read it—okay fine. Then, once they're getting their data and they're starting to come up with some relationships, I'll prompt them with questions as far as—you know—how does this relate? Or maybe sometimes you know if they've got this region here of data... what if you got data in this part? What if you really cranked up the mass or really made it light? What do you think you'll get? And so what that does is cause them to think outside their comfort zones, you know, trying to hit the extremes and the key points in the middle. That's kind of an interesting technique where—I don't know if it's a technique, but you know, sometimes the data gets so clustered, it looks like a straight line. But if they were to test the extremes right away, maybe they could come up with pre-planned points or—not pre planned—but they get as they go along that “we should get a data point in this zone—this should help to see if it's curved or linear or whatever. So, just kind of making sure they are staying on the right path—see what kind of ideas they are coming up with—even if their summation seems to be going in the wrong direction—that's what the class discussion is for—so I will let them make mistakes. I just want to make sure that the data they have is good data—so then they can go back and fix it if they have to fix their ideas—I don't want them to have to collect data a second time if we can help it.

I: Cool. So when they gather their data, and they've made their whiteboards, how do you—how do they present their findings?

R: I'll look at their whiteboards, and kind of get an idea in my head who's going to go first, who's going to go last, and what the order is in hopes it generates discussion—you know, establishing some basic ideas and going from there. And then when they stand up there, the entire class is to be focused. And the interaction is such that the students sitting in the class can only ask questions. They're not allowed to just say, “Oh, you're wrong here.” They need to ask questions in such a way—hopefully if something is wrong, or something is incomplete, the people up there will come up with it. And that thinking on their feet is tough—it's probably the scariest part for them. But also in presenting that, and forcing them to think some things through—it sticks with them—because there's a lot of emotion running through them at that time—a lot of adrenaline. Let's see—they have to ask questions, and on the whiteboards there are certain things that have to be shown—certain ways to show the graphs, and minimal amounts of information, and a summary and one equation—hopefully with units on it (laughter)-- Ideally with units on it. And from there, we take the whiteboards to a reasonable point—this is what the data showed you, this is what you say it is, and if nobody has a major disagreement, we let it stand there, and we bring up the next whiteboard. Hopefully, that offers something different. If it doesn't, maybe the first whiteboard in the discussion led us to the second whiteboard anyhow—Okay, we have confirmation—yeah—that's science—we should be

able to replicate this. And then by the third whiteboard, maybe we have a slightly different relationship going on. Maybe we flip the axes around—whatever—hopefully it's something you tweaked that makes them look at it in a different light. And then hopefully try to resolve it—what do you call that—synthesis—thesis—antithesis—then synthesis—there you go—Karl Marx at his best. So hopefully in the course of the whiteboard discussions, we all come up with something new that we hadn't considered out in the lab because it was hard to see the whole picture from just that one set of lab data.

I: All right, is this the method you use for every lab exercise then?

R: (Pause)—last year, I would say no, this year, I would say that's my goal—pretty much.

I: So what else do you have them do?

R: Well there are—of course there's the standard worksheet—but sometimes you know—and I'm trying to think this out right now—there actually will be labs—yeah, we whiteboard every lab—sometimes not at great depth, because sometimes we kind of get to the point where they've all figured it out, and that's great. But other than the labs, then they're ready for—maybe there's a secondary lab—I mean, we have this introductory lab, which is a big, big thing, but then there's secondary labs that may come off of it. And we can get those done a lot quicker because it's something just related to it. Maybe they can use the first lab—the introductory lab to help predict the results better, and so they think they have a scheme as to how things should work. And they can also have a hypothesis as opposed to just something slightly below a hypothesis—like a simple idea (laughter). But the hypothesis being—now we have data to back it up, whereas before, a simple idea is “I just think it's going to work this way.” But once we go through those labs, then we're talking about problem sets that they're working on, because now, again, they have some background—now, they may want to apply those ideas to problem sets and show some—whether it's graphing skills or sketching, mapping skills—whatever you want to call it—to help solve the problem—to show their understanding in different ways with the goal of eventually getting to the right answer for any kind of problem thrown at them that is related to the lab they've just done.

I: So how do you assess that then? How do you assess the whiteboards or other exercises you give them?

R: Um... Let's see...I don't assess every whiteboard, because I don't want every one of those to be a high-pressure situation for those kids. Usually, when I look at the whiteboards, I look at the basic parameters displayed that need to be displayed. In other words, they can come up with a wrong answer—that's not going to affect their grade. But they at least need to show the graph, show the data, show the equation, and show the summary sets in such a way that it's understandable to the rest of us. And last year was

my first year doing this, so this is kind of a work in progress—so far it's been more formative assessment than it has-- real brain assessments, but this year, I know I'm going to have at least one presentation per quarter that's like a summative grade. In other words, you have to present to us clearly. So, I still have to work on the rubric for that to be honest with you.

I: Okay, yeah. It's an evolving process. So, do you feel like you have adequate equipment, adequate space, adequate materials for being able to accomplish what you're trying to accomplish in your physics classes?

R: For the most part, yes. I mean, there's always new technology out there and you have to watch your budget, but I've been lucky—Oh, boy! Talk about one piece of advice. River Falls said give your Christmas list to your principal so that when the end of June comes if he's got money to spend, or she's got money to spend, they've got something in their hand that says "Hey, this guy says he needs this—let's spend it on that." I've gotten all six of my frictionless air tracks that way.

I: By doing the Christmas list thing?

R: Yup. That's been a big boon, because that's close to \$600 a unit I think.

I: Excellent. Do you feel your administration is supportive of what you're trying to do?

R: Yes, very much so.

I: Okay.

R: Well, there's my principal, the technology coordinator, and our curriculum director. All three of them have showed me excellent support in getting the technology and equipment.

I: Oh, you're very lucky. That's great. How do you break your grades down for a course—Like percentage-wise, what counts for what percent?

R: Yeah, I guess I have to address that this year (laughter). Here's what's going on. We're going to a combination—part of your grade is academics, but now, part of your grade is what they call 21st century life skills. What that means is that the kid who tries hard, but doesn't get it—if they showed up every day with a good attitude, got their work in, they're going to pass with a D, because those 21st century life skills will help compensate for that. On the other hand, let's say you are the brainiest one around—and I've had a couple of these—they know their stuff—at least they say they do—they do okay on the tests, so they're borderline A/B, but they don't show up every day, they pretty much just show up for the tests, maybe an occasional lab, but don't turn the labs in—Well, you're not necessarily going to get an A even though the tests may make up

80% of your grade. You've been screwing up this way by not being a good citizen, more or less, and this gets onto a report card, and it could knock them down to a B or C or something like that.

I: How do you feel about that?

R: Strongly both ways (loud laughter). I guess the reasoning behind it—if you're an employer and you want somebody you can depend upon, and you're worried about training them, then that kind of grading system would let the future employer know the employee was just that. You know, academically very weak, but as an employee, would probably do the job for you as best as they can—and around here, that's a big thing, because you know, waitresses, truck drivers, secretaries. Now, for the brainiac who doesn't do anything—we're trying to get more formative assessment. And I guess that's the whole reason behind—if we want the basic formative assessment practice, and I have found it's less intimidating for kids to say "Go ahead and try and get as much as you can, and if you get stuck, don't worry, it's not going to count as a grade, but you've got to try it." I've had better discussions with my physical science students trying that, than whatever other methods we've done in the 20 years here. So I feel there's some more to say homework doesn't count, at least as far as getting it right. But if you try the homework, you will pass. That's the end of the sword I sort of like about it. The other end of the sword, the kid that's really bright—the grade goes down—you know what? I can live with that, because it'll show up—academically, they'll get one grade, and then they'll get this life skills grade, and what if that college says "You know what? You are bright and smart, we'll let you in, it's up to you to figure out what you want to do. But we're willing to take a chance on you—even though your grade point might be a 2.9 where it should have been a 3.8, okay." So, I guess it's okay.

I: Do you feel this is kind of a way to adapt assessments for different types of learners? Is this kind of a method you guys are experimenting with to do that?

R: I think that comment is valid. Different kinds of learners—yeah—it allows different kinds of learners to happen, because we're going to standards based objectives, and standards based grading, so that at some point in time if you can demonstrate this standard—like you can communicate modern atomic model theory of an atom, blah, blah, blah—but whether they did it with a model, they can draw it out, they can describe it, or they took a test—I guess that's kind of where we're going. You can do the homework, you can—no—some kinds might not need to—but they show up to class every day, being a nice kid—hey, you got an A because you did all the things that really mattered—not the busy work homework. And yet, at the same time, that homework might be the only way that a kid can pass, because they might have real difficulty with the content, but they showed up every day—did the best job they could—they tried to do well, and we have some demonstration of understanding—they're moving on.

I: Cool. So—go ahead. (Silence) So, by the end of your course, what do you hope to accomplish with your students? What are you hoping you are able to do in the time you have with them?

R: (Long pause) Well, one immediate thing is they have a basic understanding of physics so they can go on to college. But that's really one of the smaller goals. I think that a bigger goal is that when they're approached with some sort of a problem—especially if it's mathematical—because that's really what we're spending our time on—If they're approached with a physics-type problem that involves numbers—that they feel that they have a tool that they can solve for it—even though they might not have ever solved that problem that way before. Or the problem itself is something they don't have a lot of familiarity with—you know, a topic they haven't covered—but because they might see some sort of relationship, that they might be able to come up with a possible solution. I mean that's the crowning achievement.

I: So how do you know whether or not they've met it?

R: Well, if it's the small goal, that's easy to do. And I think that's where a lot of that grading is there, you know? The bigger goal—you know—to say that I assess that—I don't think would be accurate. I don't think I would be the one assessing them—I think that's almost like a life skill kind of thing. And hopefully, while I try to keep in touch with my students so the ones who've gone onto college—wherever—If they say they felt prepared for college physics at a minimum, then I'm happy. I had one even who said, “thanks for making my physics boring in college—I already knew it.” (Laughter)

I: Excellent.

R: Yeah. So I guess that's the assessment—it's the life—when they come back and tell me.

I: Cool. So now, when you went through River Falls, were the grants part of the program then, or were you paying your way?

R: The grants were part of the program. They went from Eisenhower funds to—Eisenhower funds for science to just general Eisenhower funds where I started competing with other people. Then it turned into—what was it—some sort of rural poverty fund—that if you worked in a school and you qualified—you know—a certain percentage of your population on free and reduced lunch—living in certain zones—that kind of covered it. But at the end—after I got my Master's, then it was out of my pocket because there was no more funding, and I think River Falls admitted that.

I: Did that make a difference to you in your ability, willingness—whatever—to be able to continue to take the courses?

R: Well, I know when I first started, that was very enticing when I realized that I could have most of my Master's paid for. To me, economically, that was a no-brainer. That got me excited—at least financially—about it. Educationally speaking, to be trained – it might have made some things tougher, but I think I would have been able to do it, because it's like any other investment—it's going to cost you now, but it's going to pay off later. Right now, if I was a teacher—an undergrad, and I just got my basic broad field science, and I'm thinking about going to River Falls for physics, and if I were to see the final bill to get the whole program and the whole Master's, I'd be discouraged. Because to me, if greater—if there's a need for physics and chemistry teachers out there, then fund it (emphatic)-- It's as simple as that. The National Science Foundation did them in the early '60's and this whole big crop of teachers showed up. And now they're saying we have to educate more engineers. Well then, fund the education of the teachers. Yeah—it's so simple.

I: Yeah. It makes you wonder sometimes. Now, you've been a teacher since 1986?

R: Yup, fall of '86, yup.

I: Did you do anything else professionally prior to that, or is that what you went to college for, and that's what you started doing right out of college?

R: Previously, I had a degree in soil science, and natural resources, and there weren't jobs available, so I was working a variety of part time jobs—notable of which was coaching, which helped me get into education, because I was working with kids, and just hanging around teachers, and got a feel for things. So then I went back to school to get certified-- Ironically, in agricultural education—hey, I have a degree in agriculture—how long can this take—one, two years? The guy said three years. I looked at him and said “What else you got?” He said “Well, looking at your transcript, I can get you certified in science in two.” I just stared at him and said, “I don't know how that works, but I like science, I'm good, let's go. Let's get this program going.”

I: Cool. So is there anything else that you'd like to say in closing, because we actually are at the end of this believe it or not—in closing about your experiences at UWRF—good, bad, or ugly—is there anything you'd like to say that I missed?

R: (Long pause) It was definitely the most rewarding college experience I ever had—to be trained that way—because it stuck. It opened up new doors to me. And by no means was all of it perfect, but I didn't expect perfection. But it changed the way I taught. It changed the way I viewed students. It changed the way I learned. I think their method of training teachers—especially—well, I don't care now if you've been certified as a teacher, or you're getting certified, I think they have probably the best program I've heard of—because there's not a lot of alternatives out there. And it had a huge impact on how I conduct myself as a professional.

I: Excellent. Is there anything else you'd like to say about your knowledge and experience as a physics teacher—anything you think that I need to know about that I neglected to ask you?

R: Uff-da (long pause) ... anything as a physics teacher... let me think on this... I guess, you know—this is as a science teacher in general—If you want students to truly understand it, they have to live it. And that's what that program taught me. Not—I had to dive into it—not just look at the book and memorize it. And my understanding and my appreciation for what could be understood was magnified. I would hope every kid at some point in their life goes through a science course that's like this—this is what it's all about—getting them to understand it in different ways—you know because the typical cookbook, textbook, fill in the blank kind of stuff that's—you know—that's not truly understanding it.

I: Excellent. Well, I certainly appreciate you taking time out of your summer to talk to me. If there's anything else you think of, you can certainly email me what you come up with. And a little later in the year, I might ask for some kind of portfolio from you where you put together some of the stuff that you do, and being that it's Modeling based, I have a pretty good idea what it will look like already. And down the road, I may actually ask if I can come up and watch you work someday if that's all right. I don't know what my major professor has planned yet, but you gave me some really insightful stuff this afternoon, and I really appreciate it.

R: Oh, hey, happy to help. That way I can get that dinner out of you. (Laughter)

Interview 8 4 2010

William

I: Okay, I'm recording everything that we're talking about. Ultimately, what I'll end up doing is I have to type all of this up, and it will go into an appendix in my study. And I'll send a copy to you too so you can look it over and make sure that I accurately reflected what we talked about.

R: Okay, cool. No problem at all.

I: Excellent. What I'm going to focus on—the first part, I'm just going to get a little idea of your background and your experience and what you've taught. And then maybe find out a little bit about what led you to River Falls and what you thought about the program, or what you think about the program as you've been exposed to it, what you've been able to carry over into your classroom, and if it's affected your teaching of physics in any way.

R: Oh yeah.

I: And I will tell you I'm a former graduate of the program. I was in it from '98 until 2000, and then I defended my paper in 2001. And so I went through it, but it's been a little while, so it's kind of nice talking to people who have gone through it at different times as well.

R: Well I'm—I'll just let you know that I was trained as a chemistry teacher. So I started out with a Bachelor's degree in chemistry and a minor in mathematics from [my undergraduate university]. And I started teaching here in Stoddard in 1988. And when I was hired, I was hired to teach physics, chemistry, and math basically. I did not have a physics license, and so when I was hired, my principal at the time said, "Can you teach physics?" And I said I had ten credits as an undergrad. He said, "Great, fine, you'll be good." And he got me an emergency license through the DPI. And then it was in the fall of 1988 that I got a green card if I remember right, and it was from the River Falls physics department. I don't remember if it was acoustics or optics that I took first, I'm really not positive—I could go back and look at my transcript but—So I picked up a three credit class or two credits on Thursday nights, and I was excused from school early to go down to make it to class on time, because I needed to eat, and drive, and all that kind of stuff. So I actually committed to that class right in the fall of 1988. And I needed to take five credits—I think—to keep my emergency license, and knowing what I know now—saying yes to teaching physics and saying yes to committing to taking that many credits in physics—was really naïve of me, and I was very, very fortunate that River Falls had the program that they did. So then, I don't remember if I took a class that next spring, so that would have been the spring of '90—or not. But I know the following summer, I committed to a three week Modern physics, and I think I committed to electronics, and

whatever it was. But at that point I kind of realized that I was going to be able to finish my requirements for my physics license through River Falls. So that was—oh great, that'll be done—that'll be great, fun—and I'll be licensed, and that was good. And then it was [the instructor] actually kind of pegged me or I started realizing, "Hey, wait a minute. I think I can make this into a Master's degree program." And if I recall, there weren't many of us at that time that were considering making it into a Master's program. So I jumped into the Master's program and got committed to the whole cycle. So it was—I think I took Modern physics first, then, I took Mechanics, and then E&M the third summer. But one of the summers I remember going down to the Fermi Lab in Chicago on a school bus, and we stayed in hotels, and they paid for food, and my beginning, I was getting three credits, I was getting a stipend, I was getting room and board, I was getting notebooks, I was getting—I mean, it was a made deal. So I just really fell into that whole thing, and I ended up having to do, I think it was six credits that were not included in the River Falls program. I think that was historical and philosophical foundations of education, and methods and measurements, I think it was, with Dr. Stewart. And then, there was, if I recall, not an MEPD program, but there was a Master's of Education or something like that at River Falls. But [the instructor] wouldn't allow anyone who was his advisee to do that program. So he actually forced me to do an MST, which meant I had to actually do a paper and then I had to do an oral defense, and all that kind of stuff. And at the time, I wasn't thrilled about that, but I went along with him, because I had just a tremendous amount of respect for him. And I struggled coming up with my paper. I actually did a paper on resistance, and I did a fluid dynamics experiment with a water capacitor, and I did a thermodynamics experiment, and they were done as an introduction to electricity because—of all the education I had, and all the knowledge I had, which is a thimble-full basically, I just absolutely didn't understand electricity or electronics. And I can remember Ron Wilson just about ready to kill me, because I thought voltage flowed, and I just didn't get it. And finally at the end of his course—because I had electronics before I had E&M—that was backwards, but he was a sailor and I liked to sail, so we got along fine. I studied with Mr. Pauls, who was amazing, [the instructor heading the program] was one of my professors, I had Rob Williamson, I had Eric Blake, Dr. Shoepf was on my orals committee, and there was a professor from the math department who also was on my oral, and I did integrals and all that kind of stuff so the math guy was just thrilled beyond belief. Dr. Shoepf had just come back from a sabbatical, so he really ground me pretty good. And [my instructor] was obviously my major advisor. But in terms of, like, content and information, it was obvious that I learned a tremendous amount about physics. I really didn't have a good physics background at [my undergraduate university]. I had ten credits of calc-based physics, but not really what I needed to teach high school kids. But I think more importantly—I mean, I lived in my tent in the campground, I lived in the dorms, I learned to understand physics better, I developed friendships, and a network of people through that experience at River Falls, and I don't think the growth for me can be defined just in terms of content. I think for me personally, and for my students in science, I grew as a person through that whole experience. And to say that I learned this experiment or I learned that experiment, or I learned whatever—I learned so much about me, and how to

teach, and how to interrelate with kids, and make them excited about learning physics, and I can't even imagine my life today, and doing what I'm doing, and raising my family, and teaching, and all that—without that program. It was so powerful and such a huge part of my growth and development as a teacher and I hold Dr. Lawson in the highest of regards. He truly is an amazing person, and Ken Pauls—I don't know if you had Ken at all—but he was just a wonderful guy. I mean these guys were just cool as hell, and we had a great time. We learned a ton. We developed a lot of friendships. I can't imagine my career and me as a person now without that time at River Falls. So—

I: Wow.

R: Yeah. It was amazing. Did you have nearly the experience do you think? Or—

I: Well, I'm kind of sitting here silently in shock, because what you're saying basically mirrors my trip through, but mine happened ten years later. Dr. Lawson was my major professor also, and it was a similar deal where he kind of pinpointed a few of us—maybe he said things to everybody—but there were a few of us he said definitely should finish the program. And everything you're talking about, I went through almost the same experience, but a decade later.

I: So, have you always been a teacher? Did you go to college specifically for education, or is education just something—

R: I actually started out at [another university] to be a paper science major, which was chemical engineering. And I had kind of an epiphany about my sophomore year. I remember going through a paper mill and asking them where the paper science major is, and they pointed out some guy sitting at a desk. And I just realized at that point that my life was—I just didn't want to spend my life trying to increase paper production by three feet a year, or whatever I would do. And so, I kind of looked at where I felt I had grown the most, or what has been the biggest influence in my life, and it was actually a high school chemistry teacher that I had in Southern Wisconsin where I grew up, and her influence on me was huge, and I remember having a great time. I actually knew I wanted to be a teacher at that point, and I had eight credits of chemistry, and six of English. So as a sophomore in college, I figured I was closer to being done with the chemistry major than the English major, so I picked chemistry, which—I mean it was a stupid, stupid reason to pick chemistry, but I look at a lot of decisions I made in my life at that point in my life, and I don't think they were made with a lot of common sense and thought. But, I loved math, and I loved chemistry—I still love chemistry and math. I think I probably love math more now than I did when I got out of college. I went through a time when I really, really got into physics—there was a certain point in my career—I mean I loved it—it was my number one thing. I think right now, I've focused a little bit more of my time and energy on—I'm teaching an advanced placement statistics course, which is another whole amazing trip. But I teach algebra II, chemistry, trigonometry, ITV, AP-statistics, physics, and a principles of technology course. Then I've taught geometry,

algebra I, I've taught applied math, vocational math—so I do—I mean this is a very small district. I drive a school bus, I'm a track coach, I've been AD, I was cross-country coach for a while—this is a real small district, and you really have to adapt and you have to do lots of things, or you're just not going to survive. And I think I have adult onset ADD, so it works really well for me, because I love bouncing from one area to the next, and I don't find myself making the same jokes over and over again. I never taught—I shouldn't say that—I taught for a while at a larger high school and I taught the same class six periods a day, and that was nice and easy. But this is extremely challenging up here, but it's never, never dull. I graduated from college in '86, and then I stayed on for another year and did my student teaching stuff, because I have actually a B.S. in chemistry with a minor in math. And then I long term subbed at a large city high school and had an offer there, and I drew a line on the map and said I wanted to be up north, and I came up here for one year, and that was 22 years ago or something like that, so it's been a ride, but it's fun. I've got three kids, I live on a lake, I've got a wife that teaches first grade, I've got my summers free, I mean—I love it.

I: You're not too far from where I come from. I was born and raised in Superior—just a little further north. How many years did you teach physics before you got exposed to the River Falls program?

R: I literally started at River Falls the same fall I started teaching here. So I probably had been teaching for six weeks before the class started—maybe four weeks.

I: How well prepared did you feel going in? You kind of mentioned that at the outset, but how confident were you about your ability to handle high school physics?

R: I don't think I was any less confident in my ability to teach physics than anything else. I was strong in math. I'm more of a theoretical chemist-physicist probably than I am a hands-on applied physics kind of guy. I teach the principles of tech—it's more hands on. I guess I like the number crunching more, so I knew I was going to be okay. I worked my tail off to stay ahead of the kids in the classroom, but I don't think I was any less prepared to teach physics than I was to teach chemistry. And I felt prepared to teach kids, I think my undergraduate training was excellent in focusing on kids and what they needed. In terms of content, I think we all have to pick up what's appropriate for high school kids in our career, and I think I nailed that down after two or three years maybe, and then started fine tuning a little bit, and constantly, constantly revise what we do. But, I felt I was okay, but boy, I wasn't prepared (laughter), and it wasn't until I got into the River Falls program I realized that there was a whole world there that I just had not understood or didn't—and doing it calc-based as an undergrad—I don't know if you did calculus based physics as an undergrad, but that was tough. That was really, really, tough. And I don't know why I ended up in that track in college-- it certainly didn't serve any purpose in terms of teaching high school kids. You know, too theoretical based too early in my career. Now, I would love to go back and do calc based physics because I know the calculus and the physics well enough now, that I feel like I could handle it.

But at the time, I don't think my calc was strong enough, my physics wasn't strong enough—combine the two as an undergrad—no, it wasn't—and [my undergraduate university] did not have, I don't think, a real strong physics program either, so it wasn't great. But I muddled through that first year, and—the way I did the cycle—I started my first year in Modern physics, and that was really not the best first summer.

I: I did the same thing.

R: You know, I was overwhelmed, and I'm like "Oh my God, what am I doing here?" And I think the feeling I always had as a college kid was that everybody else in the room was really smart and I was the only dumb one (laughter) and I didn't get over that until third semester P-chem as an undergrad. And I finally realized, "Hey I know as much, maybe even more than some of these people." And it wasn't my knowledge base that was bad-- it was my confidence in my own abilities that was bad. And so, when I sat through Modern physics in Larson's class, I had no clue a lot of time what in the hell he was doing. And I think the other thing that was so amazing about Larson, was he would teach the first twenty minutes to a half hour—I was right there in his back pocket, man I knew what he was talking about, I could follow along, it was making sense—And then he would just frickin put the pedal to the metal and just kick my ass for twenty minutes—the last twenty minutes—and I just felt like an idiot. And in my mind I used to think he just had a place that he needed to be, and he kind of did a really nice job of explaining it—really developing it. And then all of a sudden it was like, oh-oh, I need to get to this point in the next twenty minutes, and he just roared the last twenty, and I would just be swimming. And I would have to run back, and then—what were they—PRT's?

I: PTRAs

R: PTRAs, they were my life-blood. I never would have made it without them. They kind of took the information that [the instructors] were trying to give us and... kind of broke it down. And I think in my mind, one of the most valuable parts of the program was putting us all in those dorms, because we ate, and slept, and showered, and peed and pooped physics (laughter). And I can remember going downtown to the bars after we had studied, and we'd literally fill cocktail napkins with physics problems for hours. And we were downtown, we were drinking beer, we were laughing, we were getting silly, but we were working on physics 24/7. And forcing us to live in the dorm room with another one of the people, meant even when you got up in the morning, you talked physics. When you walked to go eat, you talked physics. When you were eating breakfast, you talked physics. There was so much knowledge gained outside of the classroom and that was so powerful. I used to think, "I'm ripping off NSF because I'm getting free room and board, and that's just crazy." And when I got done, I'm like, "Wait a minute, NSF made—the best investment in their resources was putting us in those dorms, because it forced us to just eat, sleep, and breathe physics for three straight weeks." It was excellent—I mean, amazing.

I: So how specifically would you say the River Falls—the way that the material was presented at River Falls versus the way that the material was presented at [my undergraduate university]—you said that there was a tremendous difference and a tremendous impact in one versus another—what specifically about River Falls gave you that revelation?

R: I think the taking the information—You know, we'd be in a lecture environment and a discussion format. I think the pressure was off. I mean they weren't going to weed us out of the program-- we weren't going to flunk out of college. We were adults we were there to learn. I think that was the first thing that was the most important. They were there truly to help us and develop the knowledge base that we had, and then the art of teaching physics. And then they took that information, they were never condescending, they knew we all came from very diverse backgrounds—You know as a chemist, I took P-chem, when I got to physics I took Modern, and I said, "Hey wait a minute, this is just P-chem," and I remember Craig saying, "No, it's not, it's Modern physics." And I'm like, "Dr. Lawson, this is P-chem." "Well, okay, you're a chemist, you call it P-chem we call it Modern physics (phone beep). They never made us feel dumb, they just were there to help. And everything about the program was to develop (phone beep) us as teachers—as people so we could go back to our classrooms and help kids that would be in our rooms. And you know-- How many kids has that program affected (very emphatic)? Yeah, I got affected as an individual, but how many other kids were impacted by that program? As an undergraduate, I think it was just a matter of giving us the five credit calc-based physics we needed to meet the requirements for the degree. When I got to River Falls, those people had a completely different philosophy. Even like the coffee room, where it was—you could go sit and work problems—I can remember Craig saying that, you know the philosophy of that was so that professors and students could sit together and work on problems in a non-intimidating environment. There was never an "us versus them," never a professor versus kid. It was a group of physics people working together. And I think when I look back at that experience and how I teach today—I teach the AP Stats class, and I stress to my students from the very beginning that I am not just going to disseminate information to them. We as group are going to work together to reach a goal of learning statistics. And I stress to them that I'm going to guide that, but we as a group are going to work our way through it. It's not just me up there puking information out that we have to take in. It's how are we as a group—and I think that's something that Dr. Larson instilled in me is that—I knew he knew what he was doing, but I never ever felt like he was telling me something. I felt like we were as a group collectively coming up with solutions to problems, and that he was as excited to solve it as we were sometimes, and—it was like an art form that—I don't even know how to—it was something that I never learned as an undergrad, I know that.

I: Did you do labs in your undergraduate physics at [my undergraduate university]?

R: I think so. Yes, I know we did. They had no impact on me.

I: Were they similar to what you did at River Falls, or did one program stress something different than the other?

R: You know the thing I think that the River Falls program taught me was that you could do physics with everyday stuff. The strings and sticky tape stuff, you know, the old camcorder with the ball falling, making an air track out of a piece of PVC pipe—I think that River Falls made it okay to do physics without fancy equipment and all of that stuff. I think it was just a whole different philosophy. I just don't remember very many experiments as an undergrad. I remember a lot that I did at River Falls, but I don't think I remember a whole lot of what I did as an undergrad. That's really sad to say, but—

I: Well, that's powerful.

R: Yeah, River Falls was good stuff, so—

I: Do you think that had anything to do with the fact that [my undergraduate university] might have prepared you so when you went to River Falls you were seeing it for the second time around, or do you think it was more of the way that River Falls did things?

R: I know that [my undergraduate university] prepared me. My math was good. My problem solving skills were good. But I was a chemistry major, and so I focused on chemistry. I would kick ass in an organic lab, but I struggled in a physics lab because it wasn't my focus. And I saw math as a tool to solve chemistry problems. I never really saw—I don't think I had a real good handle on the big picture. I was there as a chemist. I was a chemistry major. I could do p-chem problems-- I loved them. I could solve triple integrals, I could do operator algebra, I could do everything I needed to do. But when I got into physics, it was just like, okay, I'll do this class, and it wasn't my thing. So when I got to River Falls, you know I realized that it was really cool, and it was something I had missed. I mean, when you're 18,19,20 years old in college—for me anyway—my focus wasn't really on learning a whole lot of stuff. It was getting a degree, meeting girls, partying, hanging out—you know, I just don't think I was probably mature enough at that point to really take from [my undergraduate university] what I needed. But when I got to River Falls, my base was strong enough that I could fill in what I needed to do, what I needed to do at River Falls. And then it just—it made me love learning, and then along the way, I learned a bunch of physics. And that's what I stress with my kids. It's—I teach—I'm teaching them to think, and I use math and science as my tool. You know, if an English teacher is teaching the same thing, they just have a different set of tools. And I think River Falls taught me to think, and it taught me to enjoy thinking—to enjoy problem solving and overcome obstacles. I mean, I learned that in p-chem in college as an undergrad, but River Falls was just—it's okay to face your weaknesses. I mean when Craig Lawson encouraged me to do my Master's paper on a topic that was just the most difficult for me—resistance was something I just didn't get. And so he said, "Let's do a Master's paper on that." I said, "Dr. Lawson, that's my weakest area." He said, "Exactly, and we'll make it one of your strongest." And that was huge, you know?

So it wasn't "run away from your fears", it wasn't "avoid what's difficult", it was "okay, let's take this on head on, and we'll overcome this, and we'll get through it." And I can remember when I did my Master's paper there was this 2 in the equation, and Dr. Lawson said it wasn't there, and I experimentally proved it was there. And I can remember literally having to get up the nerve to go into him and say, "I think you're wrong (laughter)." I mean, I think I had diarrhea for a week, and my wife at the time was like, "What are you so worried about?" And I'm like, "He's wrong." She said, "It's okay, he can be wrong." And I said, "You don't understand, it's Dr. Lawson (emphatic)." (Laughter) To have to look that man in the eye and say Dr. Lawson, I'm really sorry, but I think you're wrong, I think there's a 2 in this equation. And I had so much data to support my position. I had run that experiment I'll bet you 30-40 times to prove that it wasn't an anomaly that I was right. And when he finally said, "Boy, Will, you're right, I was wrong." I was just like—I was on cloud nine. It wasn't that I wanted to prove him wrong, but I was so relieved that he admitted he was wrong—that it was okay that I had proved him wrong—he didn't flip out on me—no that I thought he would, but he's a hell of a guy—and to go toe to toe with him and tell him he's wrong—ugh! (Laughter).

I: I never had to do that.

R: You're lucky man that was hellacious! And it was in my mind, he never made me feel that way, it was just, whew.

I: I understand. I understand. So now, with all of the experiences that you had there then, I want to ask you a little bit about what you've been able to carry over from that program and bring into your classroom. Could you comment at all on maybe how your students' experiences have changed as a result of your exposure to River Falls? Think about how you would have run your class and what the students would have seen without River Falls, and how you've been able to run your physics classes with having gone through River Falls.

R: The first and easiest thing to say is that my knowledge base increased exponentially. I mean my knowledge of physics was significantly greater. But remember again I came in as a ten-credit undergrad. I think in terms of my students, and see I think about the impact of the program not just on my physics teaching, because I teach so many other things. I think the biggest impact for my students was the concept that we are going to work on this together—that it's not going to be me disseminating information and you digesting it—it's going to be we are going to work on this collectively. I learned—and that, I think that was the biggest lesson for me at River Falls was that there were lots and lots of people involved in my learning. It wasn't just a professor, a notebook, a test. It was the whole gamut. It was a professor, the professional teachers, the resource people, the other people in my classes, the network of group—you know the groups of people you slept with and hung out with, and lived in the dorms with. I think that community of learners aspect of my teaching and what my students get from my classes is probably the

biggest thing that I can think of that I draw from the River Falls program. And it's—and obviously there's content. That's without a doubt something that my kids wouldn't have ever gotten had I not been a part of that program. The other thing I think too is that kids saw me as a student too, throughout that whole period of time. And I've continued on after that as well, and so my students recognize that I'm not just a teacher, but I'm a student as well. And I think being a student while you're a teacher makes you a better teacher because it makes you kind of realize what it is when you're sitting in class and your kids are kind of zoning out (laughter) because we do it when we're in class, too. And it's okay to zone out. It doesn't mean you don't want to listen to what Dr. Lawson's saying, or whoever he's got as a professor.

I: Unless he's got his foot to the floor and you zone out for thirty seconds, and then you've completely lost track of where he is.

R: Did he do that with you too? (Laughter)

I: Once or twice. Like you said earlier. You could be with him all morning, and then you maybe have a ten second deal where your eyes wander out the door, and then you look back at the board, and you have absolutely no idea what just happened.

R: Oh, my God. We had a guy come from the University of Michigan and talk about quantum physics and color algebra. Did you ever have that guy come in?

I: No.

R: Whoa! They hauled this dude in—I don't know where he came from—Michigan State or the University of Michigan—one of the two, and he was a leading authority in quantum physics and I can honestly remember looking over at [one of our instructors], and he looked [back] at me like, “I have no idea what this guy is talking about.” I mean we were completely blown away. That was horrible. I mean, it was a wonderful experience; it was a very interesting discussion, but, Oh my God! That guy was just—he was not even in the same planet. And, you know, I went to concerts with that instructor, and he would come downtown with us, and he was just a human being who was there to help us, you know, and I think that was just so powerful—Did you have Ken too?

I: Yeah. He kind of ran the laboratories and Dr. Lawson ran most of the courses.

R: Yeah. Did you know Ken Pauls doesn't have a Doctorate at all?

I: I did not know that.

R: No, he has a—in fact, if you ever called him mister or Doctor, he would correct you. He was not—he had a Master's degree, he did not have a Ph.D. In fact he—and did you have a Dr. James from the [-----] department for anything ever?

I: No, but I remember the name.

R: He was an ass. Oh, my God, he was just a jerk (laughter)—you can edit that out. But that guy was—he was a piece of work—he and I just went toe to toe. But he was also a Master’s degree—full professor with a Master’s degree. And I don’t think you would find that anymore at the university. I don’t think you would ever, ever see a full professor with a Master’s degree, but [one of our instructors] was one of them. He was a smart cookie though too. He was no dummy.

I: So, now based on—you said your philosophy is kind of a, “I’m a teacher, I’m a student too, and we’re kind of learning together—“ Do you feel that the way that you lecture has changed as a result of—or whether you lecture or not has changed as a result of your exposure to River Falls?

R: I don’t know, because I never taught without the River Falls experience. I teach Socratically, so—and I don’t know, I’m trying to think if they were Socratic in their method of teaching. I think Roy Williamson was more, I don’t think—was Dr. Lawson Socratic in his teaching style? I don’t think he really was.

I: I didn’t get that impression.

R: No. I’d be more of a Socratic, you know, type of questioning and leading a group discussion type format. My classroom is very relaxed. They still call me Mr. [----], and you know, we’re not buddies and friends in there, but I’m very relaxed in my teaching style. And I don’t know where that came from-- it’s just my personality. I can’t lie, first of all, so my personality has to come through in my teaching, because I’m not pretentious, I’m not uptight—I am uptight—I’m nervous, but I’m not pretentious, I’m—I don’t think River Falls affected my teaching style. Is that okay? I think it is.

I: Oh, it absolutely is. You know, as I said at the outset, even the comment that you made about Dr. James—They’re looking for the truth—they being my professors at Montana State as well as Dr. Korenic who is now running the program at River Falls. And if somebody has a problem with anything, they want to know about that too, so they—it actually looks good when somebody can tell me a few things that are wrong, so don’t be afraid to—

R: Yeah, I’m sure James is gone now-- he was old when I had him. And it’s really unfair for me to say, but I think when Eileen Korenic took over the program, it lost some of its—I mean, I felt connected to [the former lead instructor], and [the other instructors there]. I mean, those guys were like—dude—they were like—you know—I felt a connection to them when I showed up on campus anytime, whether it was taking my students down for a field trip, or something like that, I felt that they were people that I had a tremendous amount of respect for, but they were contemporaries in education. And

I think when I got involved with Korenic right near the end a little bit—First of all, they lost their funding, and it wasn't all being paid for anymore. In fact—that to me wasn't the important part—the thing was that I didn't feel that she had fought hard enough for the program. I felt that [the former lead instructor] ate, slept, and breathed that program. And I think he would have done anything he needed to to make it keep going. But I didn't see that level of commitment in her. But you know, my exposure to her was extremely limited, so I have absolutely no basis other than a few emails, my perception of her responses and stuff like that, so, it's not even fair to say. I just—the program didn't seem to have the same vitality and emphasis and energy and drive under her leadership as I think Dr. Lawson. But then—you know—he was the man, and anyone else that comes in is never going to be Dr. Lawson. So it's probably not her, it's just my allegiance to him—you know I mean, he was the man, he ran the show, he was in charge, he was all that and a bag of chips (laughter).

I: Was there anything you ran into in the program that you would have loved to have carried over into your classroom, but you found it difficult if not impossible to do so?

R: Yeah. You know, when I took optics, it was a matrix-based optics.

I: Yup.

R: And I don't think I got enough out of the course to really, really teach optics. I still feel I'm weak in optics. I still feel I'm weak in acoustics. But other than that, I think most of it – most of what I needed I could use. You know some of the equipment was kind of frustrating—that you don't have—you know, you don't have a lot of—you don't have—you know that mass of an electron experiment? I couldn't do that. You know, you get frustrated in a small district because you don't have the resources (Brief interruption for about 15 seconds). Sometimes the equipment, acoustics, optics—Dr. Lawson has an amazing acoustics background—Did you know he sang in like a barber-shop quartet or something?

I: Yeah, they performed for us.

R: Did you ever see him catch a squirrel on a tree?

I: I never saw that.

R: Oh, my God, he can catch a squirrel on a tree (laughter). I mean he literally can like reach around—you know how they run around on the other side of the tree? He had some technique—I saw it at a picnic, and I didn't actually see him do it, but I saw him with the squirrel in his hand. It was crazy (laughter). He's a big deer hunter too. I love—you know and that was part of it, too—he just was like a human being. He was down to earth, he—you know, he had that little nervous twitch, and he was just a great guy, I mean, I loved him.

I: Sure. Now, is there anything that you use in your classroom—any philosophy maybe that you’ve adapted that you believe strongly in, but that were not part of the River Falls program—something you think that maybe they could adapt that you’ve found?

R: The one thing—and this might be—you know, this is a small town thing—I try my darnedest to get as far, and cover as much as I can, within the limits of—you know, the fact that I teach a lot of different content areas—I always feel guilty about that. But I think—I loved the E&M, I loved the electronics, I loved all that stuff, but I was told by somebody—I don’t remember who, that most universities want their undergraduates coming in with a very, very strong mechanics background. And I almost wonder if the program maybe could just do a little bit more mechanics. And I don’t know how that would fit, or how that would be possible—you know, I don’t have any way to look at stars, I can’t do astronomy—you know, I can’t take them to the Fermilab—there’s a lot of that stuff that I think was good for me as a teacher, but now, I almost would like to go back, and kind of say, “Okay, now how are we teaching mechanics now—is there something new?” You know, all the TI-84’s and TI-84 pluses, all that kind of stuff—it inspires—there’s a lot of stuff that came out after I left there. So almost like a refresher type of mechanics course, or something along the lines of the ICE program at Madison.

I: I’ve come across similar material that says that mechanics—and as a physics teacher myself, about 85% of my year is mechanics.

R: Yeah, and I always feel guilty because I never get very far—you know, I don’t get to all that other stuff, but I’ve spent a lot of time with dimensional analysis which I do in my chemistry class, teaching kids how to write problems down, you know, I’ve got a Jeep, and I draw the Jeep when I do—you know, it starts out from rest, and reaches this velocity, at this time, what was the rate of acceleration—I mean I think the one thing that I was taught there was to just write a ton of stuff down and draw pictures, and visualize what you are doing. And high school kids don’t want to take the time to do that. But, could I force them, and that sucks a lot of time so you don’t get to those other areas that you wish you could get to? But I think—I don’t know—I teach all mechanics—it’s almost all mechanics. It’s good to hear someone else who doesn’t get to everything too.

I: Well that actually leads me into the last part of this interview. I wanted to ask you specifically about the way you run your classroom, and you kind of opened the door nicely there for that. If you’re starting a brand new topic in mechanics—or whatever—how do you typically initially engage your students?

R: I do—the Socratic method is really powerful for me. If we’re going to talk about friction, or if we’re going to talk about electronics—we’re going to talk about something, I mean, we’ll go so far as to go out in the parking lot, and look at the car, and I’ll draw on their experiences driving, or we’ll go outside and pour water on the ice and see that the coefficient of friction is different, and I relate it to μ , and why do we put wood in the

back of a pickup truck? I do a lot of trying to draw something that they've already experienced, or seen, or have witnessed, or can go out and see and try, and touch and feel. And then get into the theory of what's going on. When there's a race on TV, we'll talk about the race, or I'll bring a video in and show them the racecar and I'll say, "Okay, why are the corners banked?" And I draw pictures—I can draw a really good racecar on the board. And we talk about all of the things that are applied to it—you know—why are the tires bald versus tread? I really, really, really try to start with something that can anchor what we're learning and what we're going to talk about in something they've already done or experienced, and then get into the theory of it. Does that make sense?

I: It sure does. Do you ever sometimes use discrepant events? Do you purposely ever set something up where you know that what they're going to see is in direct contradiction to what they think they're going to see?

R: I have not done that—no. That's really interesting, because now, I'm thinking about—can you give me an example of how you do that, so I can kind of relate it to what I might do?

I: Absolutely. Something as simple as holding a basketball and a ping-pong ball, one in each hand, and asking the kids which one is going to hit the ground first. Just about every one of them—even at the high school level—in my experience—will say the basketball. And I'll ask why, and they'll say because it's heavier. And then when we let both of the go, and they hit the ground at the same time, there's stunned silence, and then they look at me, and usually somebody within a second or so says, "You cheated! Do it again." And we do it two or three different times, and then I have them do it to get them—because believe it or not—and you know this—very few people understand that all objects fall at exactly the same rate. Because of air resistance, they get tricked. And so that's an example of when I start that unit—When I start talking about that, I start out with that, because I know that most of them are going to guess, and they're going to get it wrong, and then they're going to have to start thinking about it. That's just one example of using a discrepant event that I've used.

R: No. And I would have to admit that I'm not good at that. So I would not—now that you've said it and I've heard it, and I can think of examples that I might use, I would certainly entertain that. And when I think of something like that, I would use it. I just have never—I guess I don't—how many different courses do you teach? Do you teach a lot of different content areas?

I: Right now, I'm only teaching two. I'm teaching general physics and general chemistry. But I've also taught AP-physics, computer networking, pre algebra—but right now, in the district that I'm in, those—and then I teach an aviation ground school class in the summertime sometimes.

R: Oh, my God. I don't know, maybe it's just me being a wimp, but man, I struggle each day just to keep the train rolling sometimes—to come up with—and I'm not very creative either. I wish I was more creative. I think it would help me teach better. But I just don't think of things like that very well. I mean, that's my weakness—you know, we all have weaknesses and strengths. I can kick butt on an AP stats problem, but I'm not very creative when it comes to things like that so—

I: See, that's where you'd bury me (Laughter).

R: But I just don't—my wife is the most creative human being known to man, and I am just like—I wear the same clothes—I mean you could virtually tell the day of the week by what I'm wearing (Laughter). I'm just milk toast when it comes to creativity stuff. I just am really bad at that. I mean I have an aesthetic sense and I'm not completely void of that, but I just am not—I can't creatively engage very well. I depend on kids coming to my classroom motivated to learn. I struggle with trying to motivate them sometimes. I struggle with what my role is here. Is my role to motivate you to learn in an elective course, or is my role to provide you with an opportunity to learn something that you've already committed to wanting to come. You know, when kids ask me, “Why do we need to know this” I'm—I don't know, you signed up for the class—why did you choose to take this class, you know (Laughter)? And I never get that in an AP class, I've never, ever, ever, had a kid in AP say, “Why do we need to know this” because they know my response will be, “Well, you chose to take AP-stats, this is the content material, this is what the college board says we need to learn, and I don't know what else I can tell you.” You know, they get them in chemistry class, so why do we need to know this? Well, it's part of chemistry, and at the end they start to see the big picture. I have really big final exams, and I spend—I love it when kids tell me, “We never did anything in this class”, and so at the end of nine weeks, we have kind of have a big a mid-term. We write everything on the board we've talked about, and we—it's just a brainstorming session where we just write everything on the board. And they are just frickin' stunned at how much stuff gets covered. But they never realize it. They don't feel it being pounded in their heads. They're just on this long walk. I don't—and along the way, there's all of this information, and they're just blown away with how much they've learned and how much we've covered, and what they know that they didn't know, and it's a—but I'm going to think about that though—that's a good way to approach stuff. I'm going to try that with my kids.

I: It doesn't lend itself to every lesson, but there are certain times when you can—the pendulum lab is another one—it's related—when you let a heavy pendulum and a light pendulum go—all things being equal, most of them think the heavier one will swing faster but it doesn't.

R: Right.

I: Or if you let one go from a high angle one from a low angle they think the periods will be different but they're not. And so you start out talking to them about that. Then when they go in the lab, they see something they didn't expect to see, and sometimes that floors them. Usually, they think you tricked them, or you rigged their experiment or something. That's usually what I get.

R: Right. That's cool.

I: So when you do teach a lesson, do you introduce all the variables to them at once—kind of like you're in high gear, or do you find it's more beneficial to introduce things gradually?

R: Very gradually. I really have to gauge where they're at in terms of – I would love to teach in an environment that's isolated from homecoming and prom and all the rest of that stuff (laughter), but you just can't. There are days where I can cover an insane amount of information, and there are days when we are just not going to get anywhere. I feel like I am pretty good after 22 years of teaching at gauging when they're ready. And man, when they're ready, I'll pour it on. But if they're not ready, I'm not going to fight it. We're not just going to shut the books and call it a day, we're going to try to get through as much as we can and get them to really understand it. But when they come and they're ready to go—and there are days when—you know there are days when you just aren't going to get anything done—and there's days when you could just teach, and teach, and teach, and teach, and they would just absorb like sponges. So, I don't—I really take my time. I really have to know where they're at. I think I have the advantage having had them in algebra II and trigonometry. I know where they're at content wise in terms of what they know mathematically, so I know—"Okay, these kids don't do the quadratic formula well, so we're going to spend more time with that." They don't—you know if I've got kids who've been through trigonometry and we run into trigonometry, which we do obviously in physics, then I'm like, "Okay, these kids are good in trig, I don't need to spend too much time with it", but if I've got a kid whose never been in trig, then I really have to back off. And I end up with kids sometimes in physics who are just there because it's the only class they could take during that period, and that they're just not going to be physics students. But I still try to make them just learn enough that they can become better consumers of physics and they don't walk away hating it. They walk away realizing that it's something that they know a little bit about but not too much, and it does affect their life, and they respect it more, I guess—I don't know.

I: How do you differentiate when you've got that kind of variability in a class? What specifically do you as an instructor do to provide a quality lesson for the kids that are aces at algebra II, and the other kids that are only in there because that was the only class that fit in their schedule?

R: Well, that's a real struggle. I hate to say this, but I do my best to bring those lower level kids up to the best that they can do, but I have a tremendous responsibility I feel to

those higher-level kids, because they are going on. They are the ones that are going to be doing things. I can't not give them what they need because I have two or three goof balls in there. So, I guess I'm probably pretty mean. I had a kid a number of years ago who just absolutely was never going to be able to do it. And I had another kid in there who was looking at becoming a professional pilot, and I had to give Cole what he needed to become a pilot, and I had to be "I'm really sorry JT, I know you're not going to get this, but we're going to try to get you through as much as we can. We're going to try to get you to pass the class. We're going to get you to understand as much as you possibly can. But we all know you're just not going to be able to do everything that's required. And I'm really hard pressed to fail a kid. In that situation, I just can't fail a kid because that was the only class available, so I screwed him to the ground and buried him? That's just not—that doesn't serve anyone's purpose.

I: Okay. So, when you're working with material in physics, there are data tables, equations, you can put things in paragraph form, you can represent things graphically. How many different ways do you use to represent material that you cover in your class?

R: I am very much a graphics, figures, pictures, diagrams—I don't do enough writing paragraphs and stuff, I know that we should—it's not something I'm good at. I do more of that in my chemistry classes, I guess. And actually, I do a fair amount in my stats class, but physics to me is hands on, graphs, tables, figures, pictures, arrows—I mean, a physics problem to me should be—and anything you do in physics—should be pictures—you know—this is what I know, this is what I'm trying to find, and here are my equations that I think I'm going to use, and here are the variables—you know—identify the variables that I know, and—you know, it's very systematic. Does that make sense?

I: Sure. It does. And when you're going from one representation to another, like, say, from a graph to an equation, to a sentence—or whatever—do you find that the students naturally are able to translate from one representation to another, or do you find that's something that requires your attention?

R: I have to guide that. It's very obvious that they can't do that. In my stats class—I know you're focusing on physics, but it's the same concept. You do a problem, you come up with a mathematical solution, and now you have to interpret the mathematical solution. You know, it's sort of like—I think about using the quadratic equation, and how the quadratic equation—the quadratic formula derives—you end up with those extraneous roots. And mathematically, they're acceptable. You can put negative numbers in and it works. In physics, it finally makes you say, "Okay, here's a negative number, equations generated this negative number. What does that mean in the context of the problem", and then address what that means within the context of this problem. Well, that would mean a negative time, or whatever it is that comes up. But I think they have a tendency to get a solution and say, "That's it." And to force them to go on and say, "Okay, now what does this mean in the context of this problem—"I mean we spend a

lot of time with that. Like, do you do the order of magnitude questions with kids in the beginning of the year?

I: Sure.

R: Yeah, and oh, they just hate those things. Who cares how many piano tuners there are in New York? How many hamburgers come from a cow? I have no idea—well, neither do I. But let's make some assumptions based on some previous knowledge that we've got. And then, they're forced to think. And like okay, now, how many hamburgers make a pound? "Oh, my mom makes two hamburgers out of every pound." I'm like, "You're ridiculous. You don't eat a half pound hamburger at your house every night." "Well, I guess not." Well, who would know then?" "Well, I'll just call my mom." "Well good! Call your mom." "Mom, how many hamburgers"—you know (laughter). They just can't—and I think they're—they just want to be done. They're like, okay, $t = -5$. Okay, what does -5 seconds mean to you? "I don't know, it's what the equation said. Here, I'll show you my work." No, that doesn't make any sense to me—it doesn't make any sense to you. What does that mean (laughter). Well, let's look at where that number came from. How did you get that number? "Uh, I put it into this equation. I used this one." Well, what does that equation tell you? "I don't know." Well—that process—that takes a third—probably two thirds of teaching physics is "What does that mean?" What does that mean in the context of this problem? How can you interpret what that solution means? That to me is—that's the cool part of physics. I get to take all my math tools, apply them, and then we can just sit down and say, "Okay what does that mean in the context of this problem?" And we go back and look at what we were told. We look at what we know. You know—how many times do you have to deal with kids that don't realize that when the problem says that the car starts from rest that initial velocity is zero? It takes me a week or two to make them realize that. So—"There's really no information here." I'm like, "Yeah there is, read the problem. Read what it says. What does that mean? Starting from rest—what does that tell you?" "Well, I don't know (laughter)." Well, is it the distance that they're traveling?" "No." And it's like—that to me is—you talk about—one of your questions earlier was you know, do you get through a lot of information? I literally could spend twenty minutes really making them think and understand what is in the problem. How many times do you read this problem before you embark on a solution? How many—is it okay to think this is the equation I'm going to use instead of just putting numbers in and saying, "Wait a minute, there's two unknowns in this equation. Something is wrong here." Okay, then is it okay? "Well no, it's the wrong equation, I screwed up." No, you didn't screw up, you've just eliminated that as a possible solution. So let's back up rethink the problem, we're not going in that direction again, because we know that didn't work, so let's not erase it, let's leave it, then, we'll move on in a different direction. But, oh my God! It takes a long time. You know—and that to me is the most fun. I mean, you get into that discussion with kids, and who cares how much physics you get done? If they can learn to think, they've got two thirds of the problem solved before they've even started working it out.

I: Sure. So, do you do lab work with your physics students then?

R: Oh yeah. Not nearly as much as I would like to do, but we have an air track, and we do as much as we really can—obviously not as much as I would love to be able to do. Again, I think part of my problem as a teacher is that I think I get into the theory of things probably more than I should. Did you ever have anyone in any of your classes that was into that Conceptual Physics by Hewitt? Do you teach with that at all?

I: I have that textbook and I use it as a reference.

R: Was there a Jody Schaller that you ran into at all from Milwaukee?

I: Absolutely.

R: Oh, my God, she was a Paul Hewitt fiend. We used to joke that if Paul Hewitt showed up, she would have ran off with him for the weekend.

I: Was she one of your PTRAs, or was she a student in there with you?

R: Oh, she was a PTRAs. And then, did you have a Jim at all?

I: Jim Timmerman.

R: Jim Timmerman. Yes. That guy was amazing.

I: And Bryce Baker.

R: Yeah, exactly. I had the same three. Bryce, in the beginning, was a little pretentious, but once I got to know him, he was a great guy. If you believed everything he was telling you, then—I mean—If you swallowed it and you wanted to bow at his feet, he'd let you, but he was really good. Jay was amazing. Jim knew his stuff and he could explain it. He was down to earth, he was a football coach, he was a good guy, he knew physics, he was—

I: He became a major proponent of Modeling, which was just being born right about the time you were going through that program—the Modeling physics curriculum, I don't know how familiar you are with it, but it's all lab-based.

R: Yeah, I can imagine he would be, and I think that would be great. I hate to sound like a broken record, but sometimes—if I really jumped on the physics bandwagon and got into Modeling, and did labs all the time, and I got into the chemistry stuff and did labs all the time, and got involved in the AP stats program 100%, I wouldn't have any time left for anything else in life (laughter). I always feel guilty—you know—because I talk to you and I get motivated to—and I start thinking about my physics and doing the right thing, and blah, blah, blah, and I get emails all the time from the AP college board, and

I'm not doing the job there I should do, because I haven't been to a single session, I'm not a reader yet—there's only so much you can do. There's tons I would love to do, but I just—and Modeling, I should look at Modeling, I would be interested in it. Whether or not it is something I could adopt at this point in my life—you know, I'm sure I could, I don't—My philosophy on technology is probably really, really outdated. I teach my kids how to do the problems with a pencil, paper, and an eraser. And we substitute, and we use the calculator as a tool, and then they—Once they understand better what's going on, then they adopt the technology better than even I do. So, I'm not really a big technology guy, I'm not against it, but you'll never see me do a power point presentation, because I grew up watching people try to impress me with their power point techniques, and you forgot what you were learning. You were like “Look, it faded really cool from the left,” and I'm like “What the hell does that have to do with anything?” I want to learn what they are telling me, but I don't want to get caught up in the technology. The same thing is true in my math courses. My kids know what a sine curve looks like, and if you ask them what the sine of 330 degrees is, they're going to tell you it's an irrational fraction if it needs to be, or they'll tell you it's a fraction. They're not going to give you a decimal. They're not going to run for their calculators. They're going to look up in the sky, and draw that quadrant and think, okay 330, that's in the fourth quadrant. That's going to be one half—yup—negative one half. And then they'll—so I'm probably bad that way—the next physics teacher in Stoddard will be a technology guru.

I: Well, when you do a lab, how does the investigation typically begin?

R: We'll discuss whatever it is that lab is going to be about. I'll have the equipment set up—I actually a lot of times have them help me. I find that they get so intrigued by the stuff that I'd rather have them play for a little while with it, and then figure out what's going on. You know, if we're going to run with the air track, I'll set the air track up and I just say, “Why don't you just go play with it for a day and figure out what you're doing.” And then they just play with it, and they're like, “Hey we could do this, or we could do this, or this.” And I'm like, “Here, try this.” And they're like—then the experiment kind of starts and we talk about collecting data, and we talk about how we can manage collecting this data, and—I took a class as a post graduate as a specialist at Mankato, and it was called experiential ed—I don't know if you've ever done anything with that at all?

I: I'm not sure.

R: Experiential Ed is—this is not—this is not, and I didn't like this—here's an experiential Ed experience. They took me up to Lake Superior and they put me in a kayak with a total stranger. Then they said, “There's an island three miles out there—go for it.” And I thought, “Okay, wait a minute here. What happens if I tip over?” [They said] “Oh, you'll figure that out if you need to.” I thought, oh, good God! That's not very smart. But experiential ed wants you to just play, and out of playing, then you kind of start saying, “Wait a minute. I think I want to quantify this, and—.” So, if I'm going to run an experiment, I—what a lot of times I'll do is kind of have the stuff sitting out,

and then we'll kind of go back as a group, and we'll start kind of putting things together and then we'll start saying, "Well, we're going to have to collect this." Then we work at whose going to collect the data and how is this going to be run? When I do my water capacitor experiment at the end of the year, I have it set up in the back of the room and then they're intrigued by it and they're like "What is that?" You know, it's a water capacitor. "Well, how does it work?" Well' let's go back and take a look at it. And if we do this, and then we do that—"Wait a minute now."—I love that experiment because it's a logarithmic relationship—I love seeing logarithmic relationships—It's like the only reason I think that I do that experiment—and then they get to see this really cool logarithmic—it's no different that discharging a capacitor through a resistor, and then you're looking the current or whatever it is and the time intervals, and it's like it's logarithmic there too, but—

I: Do you have it pretty locked in--Are your lab experiments more open ended, or do you pretty much tell them exactly what they have to do, and when they have to do it?

R: No, I don't tell them because I have found that they'll come up with sometimes—I mean, again, like the Socratic method—I have an ultimate goal for what I expect them to get out of the experience, but how we get there follows pretty much—you know—it's not that it's going to be completely crazy and different, but I certainly don't want to stifle anything along the way. I mean, 95% of the time the experiment ends up going the way I think it's going to go, but sometimes things come out of it, you know, they come up with a way of trying something, or a different way of doing something. You know, I—running the stairs and doing that horsepower lab, it's tough to find stairs. I can remember back when we did ticker tape labs. Remember those, were you a ticker tape guy?

I: Oh yeah, the spark timers.

R: Oh, my God. Yeah, we had—oh. And that was a cool experiment because—you know all that ticker tape, and the kids could see it and they were like, "What's that?" I think that's how I probably run more. It's just putting it out there and they kind of get curious about it and then we go from there. But no, I try not to keep it too closed ended. I think they need a little bit of input, but I still guide. I still want the experiment to—I want them to get out of it what my goal is for them to get out, and if we get more out of it, that's great, but certainly no less than I hoped for.

I: So when they're gathering data and getting familiar with the equipment, what is your role during that process? What are you doing while your students are conducting an experiment?

R: I have learned that it is best for me personally to—not walk out of the room and go to the lounge, but really step away and let them get confused and frustrated, and—I try not to because it's really easy—it's no different than—I don't know if you're a parent or not—but it's really easy to step in and do for my kids. I kind of want them to do it on

their own. So if I tell my son to go wash the van, I don't want to go out there and do it with him or for him, because then I'm just going to do it. So, sometimes he's not going to do it the way I want him to do it, but ultimately it's going to get done. So I'll sit and I listen to them. And I'll watch them, I'll talk to them, I'll ask them questions about what they're doing. But I really, really try very, very hard to stay out, because I just don't think that they're going to learn—you know the physics experiment and the physics is fine that they're learning—but simple things like, "Okay, Johnny took and wrote down all the data, but Johnny's been sick for three days. I don't have any data to work on." "Well, what did you learn from that?" "Well, don't let Johnny write it down." I said, "No, it could have been anyone that could have gotten sick. What did you learn?" "Well, everyone who leaves the lab should probably have a copy of the data." "Exactly." You know, and if I had said, "Everyone make a copy of the data, because what if Johnny is sick tomorrow", they're going to be like, "Wah, wah wah", they're not going to listen, and—but if they can try it on their own, and they can play, and they can make mistakes, and if it takes us three days, and the experiment fails, then we'll all sit down together and say, "Where do we think it failed?" "What do we think we could have done differently?" "What could we have done better?" "What did we do good?" And then I'll—you know, if the frustration is so great that they're just not going to get anywhere, then I obviously have to step in. But I really, really resist the temptation to step in, because I would rather do the experiment myself than sit and not do it. That's hard for me to just sit and watch them do stuff. I like doing that crap—I love doing that stuff—work and problems. I love banging my head against a problem for a couple of hours until I figure it out. I mean, that to me is candy. I'd rather do that than read a book any day.

I: So how do your students typically present their findings when the lab is done?

R: I'm old school I like a lab report. I like a purpose, I like it typed up, I like it presented. I grade it—I kind of use a rubric. I would have to say in terms of most of my experiments, I probably spend most of my time reading their conclusions, and I focus a lot on having them write a good conclusion statement so that I can get out of that what they think they learned from the experiment. I guess I'm—I don't know if that's old school, or if it's just my chemistry background, but—

I: If it is, I'm old school too.

R: I like lab reports. I like titles—I like a title page. I like figures if they can't do it on the computer, and they need to get good graph paper and draw a good figure. I've got French curves in my room, and they can do them that way. I like sharp pencils, and—I tell them that any graph that they make, if it falls on the floor, anyone should be able to pick it up and figure out whose it is and where it belongs. It shouldn't just say John on the top, it should say, "John Smith, Mr. Koball, Physics, April 10, 2009... there should be enough information that they should know what's going on. We talk a lot about how to organize. I would have to say that was something I probably learned in writing my paper, with Dr. Lawson, and then writing my specialist thesis too, was that writing a big

document—you know—putting that document together is as powerful an experience as the actual experiment was in many ways.

I: Yes (laughter). I understand. Is that pretty much how you do it with every lab then?

R: Yeah. I would have to say that's pretty much the format I follow, yeah.

I: Do you ever have them do anything with whiteboards, or present orally in front of the class, or anything like that?

R: I have. I have not done the whiteboard thing. I don't force the oral thing. I guess I've just found I've had too many kids that absolutely so struggle with the oral presentation that the value is just not there. When I teach physical science, I try to make my kids do an oral presentation just to get them up in front of a group. But I don't do real well with—what's that thing where you're supposed to let kids express themselves any way they want, and present material—you know, if some kid wants to draw—paint a painting—?

I: Multiple intelligences.

R: Yeah. I struggle with that too. It's kind of like—I think in the physics world, you have to learn to—I don't know—when in Rome, do as the Romans do—I don't know—it's probably the bad way to do it. But remember, I'm like—in my late forties, so, you know—it's not that I'm old, but it's sort of like—sort of the way things are—like, you should write in the third person, you should indent certain ways—I guess that's part of why we have really young, cool teachers with new ideas, and why we have old guys like me that (laughter) sort of stick to the—I don't know how old you are, but I'm just sort of—I don't think there's anything wrong with being old school sometimes. Whiteboards seem cool, but—I don't know—

I: You're being kind on hard on yourself, but that's all right. People kind of accuse me of the same thing. So when the kids do a lab, how do you determine if they've met the objective of the investigation? How do you base your decision on whether or not they got it?

R: Well, if it's kind of a closed experiment—like if we're shooting for a value—like if we're calculating “g” or something like that and if they get 8.9, or 10.1, or 10.3 or—I don't really care about the numbers that they're getting necessarily. When they walk away and they just kind of get it, I feel like we've met our goal. I mean, I think that—I can remember Dr. Schoepp was on my oral committee. And in my Master's paper, I had used the percent error, so I would calculate a percent error. He flipped out. He said that percent error assumes that you know the right answer, therefore, why would you be doing the experiment? Percent difference allows you to say, “I think this is what it was supposed to be, and this is what I got, and this is the difference between the two.” So if

you're going to work percent error, it just means you already knew the answer. Percent difference allows you to sort of compare two values. And so, he actually made me go back and change all of my percent errors to percent differences, which Dr. Lawson thought was really funny, but I did it because Dr. Schoepp was one I respected too. But I don't want the kids to feel that they have to do it within two tenths, or one tenth—it's not analytic chemistry where you're getting graded by the mass of product. And some experiments just flat out don't work for whatever reason, we just can't get it to work—you know we try something new, and it fails miserably, and—is that a bad experiment? I don't think so. I think it's as valuable as anything else you can do. I mean you just kind of chalk it up and say, "Whoa, that just didn't work at all." We talk about what happened and why don't we think it worked, and what do we think we should have done better, and then me just kind of move on. It's part of life. Not everything I've done in life worked.

I: Sure. So, do you feel that you have adequate equipment, space, resources and things to do what you need to do in physics?

R: For the most part. I think the time is the problem I don't have enough of. I don't have enough time to prepare for everything I do. I think that's one thing I wish I had more of. Or—

I: You said you're teaching how many different classes at one time?

R: Oh, my God. I think I teach five or six; Algebra II, Chemistry, Physics, Trigonometry, Principles of Technology and Statistics—I teach six classes in an eight period day. But I have Principles of Technology and Trigonometry are semester long courses, so I teach five different classes during the day. But I have two that are doubled up and I get a 45-minute prep period or something like that, so I just don't have time. I mean, I have—I'll tell you that's what it is—it's the time.

I: Do you have the Verneir equipment or anything like that? Do you have any of the electronic data taking equipment or anything like that in your program?

R: I do, and I haven't utilized it. So, I have a little bit of that stuff, but no, I would have to say I'm not good at that—no.

I: Okay. It's there you just haven't been able to implement it?

R: Yeah, we've got a motion detector and some of those things that hooked up to TI's. I just struggled with keeping up with the technology part of it-- it is challenging to me personally. So I find myself going back to older tried and true kind of stuff that I can just—old fashioned experiments that don't require all that stuff. That would be a weakness of my program. I mean, if someone were to ask me what a weakness of my program was, it would have to be technology. I'm just not techno savvy. That's my glaring weakness (laughter).

I: Well, we all have to have some of those.

R: Yeah I know. I have more than most, so—that's all right though (laughter).

I: It sounds like you're plate is pretty full. When you're assessing your students, do you—is it only summative assessments—that is, things that you're marking with a red pen, or do you use formative assessment techniques also?

R: I would have to say that I do a lot of very subjective grading—especially in physics. I guess I have a set of goals that I hope we reach, and if we reach those goals, then I feel they have met my expectations for the course. Physics is really not as cut and dry in terms of grading as my other courses, just because of the nature of the beast. You know, when I've got a kid that's just not up to speed, he or she is going to pass—we'll sit down and talk about what they've been able to accomplish. I would say I really steer away from whatever the red pen stuff is, because that's just not going to work in that context. And I—you know, I would much rather have a kid come in and take my course knowing they're probably not going to fail and at least be exposed to the physics as opposed to steering clear because they're afraid of getting chewed up and spit out.

I: So do you have a set percentage, like labs count—

R: No absolutely not. I grade on a modified t-scale, or a z-score. Do you know much about z-score grading at all?

I: Certainly. Well, I don't know if I ever used it for grading, but I know what a z-score is.

R: I actually take the z-score. I actually calculate a z-score for anything that I do. Then, I change it into a t-score, which is no different than like the ACT and SAT do. They take z multiplied by 5 and add sixty or whatever everyone does. But I grade my courses based on a modified z-score. I don't tweak the z for GPA. There's a way to modify it a little bit, say if you've got real high potential students than you should decrease the amount of the weight of the standard deviation—I don't do that. But physics is another beast. I really, really look at what did they accomplish?. How did they use their time? I want them to turn homework in—obviously they have to. A lot of open book things, a lot of—I let them do group work. I guess I've just found here in Stoddard anyway—and I don't know if it would be everywhere—but these kids need to be exposed to physics and stuff without that fear of failure way more than they need to be—need to have physics and stuff ground into their heads.

I: Demographically, you have a larger segment of underrepresented people in that part of the state too, right?

R: Actually, we do. The number one factor for us is poverty. We have like 56% of our students on free and reduced meals, and 75% of our students are living in poverty.

I: Wow. And how big is your school?

R: K-12 or early childhood through 12, we're about 600.

I: Wow. So, how big is a typical senior class?

R: Between 25 and 35. So, I think when you hear me say that my grading and my objectives don't sound very concrete in physics, I will go toe to toe with anyone who tells me I need to buck up my grading scale and push harder. Because I can assure you that truly, the number of kids that come through my school who are truly what you and I would consider physics students—if I get one or two every three years, I'm probably lucky. Now, I've got kids who have gone to the Air Force academy, and I've got doctors and lawyers—we all do. But in terms of how many kids are truly physics kids, there just aren't that many. But I'll tell you, they come into my room, they're scared, they don't know what they're doing, they're living in an environment with their families or their extended families—whatever they've got going on—that you and I can't even imagine how some of these kids are functioning. And if they can come into physics and they can just learn a little bit of physics, and learn to enjoy it, and not be afraid of it, I've met my goals. If they can't do the problems, if they don't understand the labs, or if they can't type because they can't get access to a computer or whatever—I mean—I'm just going to throw them out? That's just doing no one any good. So I feel like if I can get kids to come into my room and just be involved and—I've had kids who have walked into my room and they've said, "I know I'm going to fail you class, but I'm going to learn more by being in this room than anywhere else, so I'm going to come into this room." That to me is a sign that I'm reaching my goals. Those kids are coming in, they know their not the material to make it, but they're going to sit in there and they're going to do their best, and they're going to try. And they know they're not going to ever reach that level that would be considered passing, but there's no way they're going to fail my class, because they at least gave that a shot.

I: So do you adapt anything? Like, do you specifically adapt assessments for different levels or different types of learners—that sort of thing?

R: Yeah, it's me sitting down next to them and encouraging them. I'll give the kid all the help they need. I won't tell them how to do the problem, but I'll encourage them, I'll encourage them to write something down and say, "Okay, what you've written down here, can you—think about what we did in class?" Oh yeah, you have to, and I've got—I call them life jackets or kids that really, really, really need extra help—they'll get that help from me—if they need extra time to do stuff, I'm very, very, very flexible with that. Now, when you move into like an AP stats course, or an Algebra II course, I don't have quite the flexibility there that I do in my physics courses. So, I'm probably not going to

be as—compassionate maybe is the word I might use—I don’t know, I’m not a real warm fuzzy guy, but if I can get them in physics, I want them to try. Unfortunately in Algebra II, I can’t be so warm and fuzzy. There’s an objective, there’s content that needs to be covered because they’re going to take the ACT, and they need to know how to do those certain things, and so those courses, I’m a lot more structured and more rigorous probably. In physics, we get the rigor, but we have to modify it to allow those kids who just want to come in and learn—I don’t know—does that make sense?

I: Absolutely it does. And I guess just to kind of wrap up—because you’ve told me a lot. I guess I didn’t say at the outset—There are no wrong answers to these questions. When I did this survey, I was looking for people that teach physics that felt like maybe they got something out of the program, or maybe there were some things that they thought were wrong with the program that they’d like to speak out about. But what we’re trying to do is figure out what the physics teaching community would like to have, or what they think is important for training the next generation, and what they’ve found that works in their classrooms so that we can make it better for the generations that are going to come after us.

R: Like I said earlier. I think there needs to be a sensibility that physics is frickin’ scary to a lot of people, and it’s okay to be intimidated by it. That’s natural—it’s not okay, you shouldn’t feel that way, but it’s okay, and you can overcome that. So, the River Falls program took me in and said, “Okay Wayne, you’re a chemist and you’ve got the math background, you’re not a physicist, but that’s okay, we can get you there. We’ll teach you enough about physics, we’ll make you understand and appreciate—we’ll make you a better problem solver, and you will learn physics.” I mean, I was intimidated initially when I went into Dr. Lawson’s first class, and once I realized it was okay to not know the answers, and not be a physics geek, it was okay, and then I became one (laughter) I was like, “Oh, this is pretty cool stuff—I like this stuff.” But, I think that the next generation needs to know it’s okay to be confused, and it’s okay to be frustrated, and it’s okay to not know what you are doing, and I think that’s what needs to happen. You know, I don’t think you’re going to get a lot of physics teachers per se who are going to come into the profession as physics majors. They’re going to get a lot more people like me who start out in one area and then end up in physics. I mean, why would you become a physics teacher and barely make \$50,000 a year when you could become a physicist and make \$150,000, you know—I mean it’s (laughter).

I: You know, I get asked that question every year.

R: Yeah. I’ve got my Bachelor’s degree in chemistry, I’ve got my Masters from River Falls, I’ve got a specialist degree—I teach—I probably could make more money—that’s not really important to me right now at this point in my life, but are we going to convince young people to become physics teachers when there’s just not a lot of—and it’s not even the money that bothers me—it’s the respect. I just wish people respected what we do. I wish people had respect for me, and my profession—not necessarily me, but my

profession and said, “Teachers are important. Teaching is important. This is an important thing, and I should value what they do.” And I don’t think we have a lot of that right now. I think that’s probably one of the most frustrating things is that I just don’t think people respect or value necessarily what we do. And it’s not an easy job—and I mean—It’s okay not to know—there’s a crap load of physics out there that I’ll never understand—it’s all right, you know?

I: Sure. So, is there anything else that you’d like to add that maybe I didn’t bring up, or maybe I didn’t ask a question exactly right—just one more chance to say anything you wanted to?

R: No, I just think that the program at River Falls like I said earlier on—it went way beyond making me a better physics teacher. I think it truly made me a better person. I truly, truly feel the person I have become in all aspects of my life can be in many, many, many ways be attributed to what I learned at River Falls. You know, it was the summer I was getting married, I was living on campus and my room mate at the time was Joe Knight from down near Chetek, and—

I: The arrow guy.

R: Huh?

I: The arrow guy.

R: Yeah, that was his son. His son actually passed away, I think. The younger Joe passed away. But I had grandpa, the old one—he helped me. I was nervous about getting married, he told me it was going to be okay. I mean it was—those experiences—there’s just no way you can put a value on that, you know? It was huge. It was—it’s who I am. I mean, I owe a big, big part of my life to that program, and I think I’ve got multiple students who have benefited from what I think was the teaching I was able to provide because of it, and a huge amount of respect for [the instructor] and that whole crew. And so, it was a great experience. I have nothing but good things to say about it. I have fond memories, I had great summers, it was a lot of fun, I learned a ton, it was—the whole thing was good.

I: Excellent.

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Pam

I: Okay, so I have a tape recorder playing now that's going to record everything that we talk about. And when I get this done, I will send you a copy so you can look this over and see if what I typed down was—makes sense with what it was that we actually talked about.

R: Okay.

I: My first question is do you have any professional experience in fields other than teaching?

R: Well, I did AmeriCorps before I started teaching, but I was in the schools with them and I was doing like an alternative to out of school suspension, but I don't think that's really a different profession.

I: Okay, so you taught, but it was as an AmeriCorps volunteer?

R: Correct.

I: All right, how long did you do that?

R: I did it for just an academic year.

I: Where in the United States were you when you did that?

R: I was volunteering in Seattle, Washington.

I: Okay. How many years have you been a teacher—and you can count that AmeriCorps year I think.

R: Okay, well then I guess I just finished my eighth year, and I'll be starting on my ninth year.

I: Okay, and in those eight years, what have you taught in that time leading up until now?

R: Okay, I've taught biology and integrated science which was sort of a ninth grade level course where first semester was chemistry, and second semester was physics—like entry, just basic chemistry and physics. Then I taught honors biology. And when I moved here to Salt Lake, I taught biology again, and I taught earth systems, which is another, sort of,

ninth grade integrated class that incorporates weather, geology, environmental science and astronomy.

I: Okay, so you taught physical science, and you taught physics maybe in a physical science format—

R: Format, yes.

I: Have you ever taught a course actually called physics before?

R: I'm going to be teaching physics next year—this upcoming academic year. And I'm going to be teaching—it's not a mainstream physics class. It's going to be—I just finished my ESL endorsement—so it's going to be physics for English language learners. Salt Lake City has a lot of refugees that come in, so they're sort of tracked into a different—I guess track—of taking science classes. They're not really in like—I mean, some of the kids in the ninth grade level don't even know what the three phases of matter are. So, I'm going to be getting students that are in their third year—they've been there at least three years—and they've been recommended by their previous science teachers to take physics.

I: Okay. So, is this something new that your school district started up? I guess the question I want to ask is what led you to teaching physics?

R: Well, when I was in Milwaukee, I saw that River Falls was offering some physics courses—some grad classes in physics, and that it was part of a grant. And so, I thought that it would be really fun to teach physics or at least take some classes on it—because my major is in biology—as well as the life sciences. So I started taking those classes and I just realized I could just continue with the program—you know—the Master's program. I didn't realize that that program is probably more for physics teachers rather than for teachers that don't normally teach physics. But I feel that there's more of a need for the math-based physical science teachers than more of the life science teachers. So I'm excited—there's definitely a need for—This is the first year my school is going to be offering ESL physics or ELL physics because a lot of the teachers haven't been—they're not endorsed in ESL.

I: Is it just one other language you're anticipating, or are there going to be multiple cultures with multiple languages all coming together?

R: It is multiple. There are going to be multiple languages put together. We decided as an ESL department before the school year let out, and we're just ordering a ton of different dictionaries—many different dictionaries (Wind distortion) – we have funding for different dictionaries, so we have (inaudible—wind distortion)—

I: Oops. I kind of lost your last ten seconds there. You were telling me the different languages.

R: Oh, okay (inaudible).

I: You're not going to believe this, but I lost you again. I think it might be kind of windy?

R: Oh, is it windy on my end?

I: Yeah. Okay, now you're loud and clear.

R: Okay, all right so I was just saying we have a lot of Polynesians, Bosnians, we have a lot of students from Africa—different countries within Africa—and of course we have a lot of Hispanic students.

I: So are you versed in all of these different languages?

R: No, no I'm not. I did minor in Spanish.

I: Okay.

R: So I have a little background in that.

I: When you are designing this course then, what are you being sensitive to—What's the word I'm looking for—How will this course be different than a students signing up to, say, take my physics course which doesn't account for different languages?

R: Well, there are different strategies that allow students to conceptualize new vocabulary terms. Because some of the students—if they have been formally going to school—they understand like—they know what the words mean in their own home language, but they don't know what it means in English, or they don't know what the word is in English. So I think my class operates a little—will offer a lot of different activities and tasks that will allow them to become more familiar with the language—through writing, speaking, listening, and doing.

I: Will this class be algebra based, calculus based, or maybe more conceptual based where you don't worry about numbers at all?

R: It will probably be more conceptual based.

I: And what's the grade level?

R: Most of them will be juniors and seniors.

I: Okay. So, this is something new that your district is putting together. I'm actually very curious to hear more about how this goes, because you're the first person that I've

spoken to that is truly trying to tackle physics and language barriers simultaneously, so that's exciting. How—since you haven't actually taught a course formally called physics before, how prepared do you feel?

R: I feel pretty prepared—I mean I've already taught—you know physical science. And I think that—I've been told that this course will not necessarily be up to the level of regular physics, just because of the language barrier—communication barriers. But I feel like there are a lot of online resources that I can use. And I think that there are physics teachers at my school—they're fantastic people. Taught at the college level, one has his PhD in physics. So I feel like I have a lot of support if I run into any problems. And we have one of the best ESL departments in the district. And I feel like if I'm teaching ESL, Salt Lake City is probably a good place to be teaching it, because we do have a lot of resources.

I: What part do you think the River Falls has played in how well prepared you feel going into this fall?

R: I think it's helped me quite a bit content wise, since I didn't major in physics. I've just taken the basic requirements that I needed to when I was in college. I think that the summer sessions were really intensive for me because I wasn't just reviewing some of those concepts—I was learning them. I think it was a good opportunity for me to collaborate with other teachers that teach it. I get to hear how creative they are and how they structure their class, and what kinds of activities that they do. It also helped me sort of—I think the program is just amazing. I think that the way that they have it set up—it's just such a community. The teacher that teaches it teaches it every year—at least when I was going through it—the same lab person—and they really focused on progress. And they also had volunteers from the community that have taught physics help. And you were in a dorm with all the other students, and it was just a really great experience to learn—an intensive experience to learn physics and also to become a better teacher.

I: How far though the program have you gone?

R: I've finished all of my coursework except for one education class. I need to finish an educational psychology class, and then I'll be done with all of my coursework. I'm just working on my final project right now.

I: What years were you in?

R: Let's see. I think last summer I didn't take any classes—so that was 2009. 2008, I was in it, 2008—I think I skipped the 2007. 2006, and 2005—those three summers I was in it.

I: Okay. Which core course did you start with in the sequence? Did you start with Modern, E&M, or Mechanics?

R: I started with Electricity and Magnetism.

I: (Laughter) And when I started it in 1998, I started with Modern, so I—did you feel—How did you feel coming in starting with the E&M knowing—I'm sure you found out rather quickly that the normal starting sequence is Mechanics. Did you feel like that was a challenge for you?

R: I never knew what the normal sequence was. I don't know—I kind of felt like it was what it was—I mean, I think there were other students that kind of had staggered entry points along the way, so—and there were quite a few students in my class that didn't start at the same time I—I guess I never knew. I thought it was a great spot, because I was familiar with electricity and magnetism. I think if I had started with Modern, I don't know if I would have finished—even though that was my favorite class.

I: Sure. And once I started Mechanics the second year, then a lot of what we did in Modern for me made more sense because Mechanics kind of laid the groundwork. But I was curious because different participants have come in in different places—and you can start anywhere, but in a perfect world, they all said Mechanics is where you should start—it just doesn't work out that way for everyone.

R: Yeah, I'm sure.

I: You said you've completed undergraduate physics before?

R: I took two semesters. That was my requirement.

I: Was that calculus based, or algebra based?

R: It was algebra based. I majored in biology, which is non-mathematical based, so I really didn't (inaudible) my requirements. I really didn't need math—I tested out of my math. So I didn't need calculus.

I: Okay. So, having gone through the undergraduate experience, and now having gone through essentially the entire River Falls program, how would you compare the two? Was there a difference between the two—and if so—could you elaborate on that a little?

R: The difference between my undergrad experience and my graduate experience in physics?

I: Yes.

R: I had Eric Blake actually for one semester in physics, so—I mean I just—He’s awesome, and he’s a great professor, and it was nice to see a familiar face when I went into physics at the graduate level.

I: So your undergraduate physics was at River Falls also (surprise)?

R: It was.

I: Interesting. I think you’re the only one that’s going to fall into this category too, so this will be interesting. I can break it down for you a little bit. There’s a few things I absolutely want to hear about the comparisons between—what for instance—what about the way the courses were structured? Just the way the material was laid out—the syllabus as it were—what was—can you comment on one versus the other that way?

R: I don’t remember how the undergrad was organized. I had Madsen first semester, and I had Blodgett second semester, and I think they went sequentially through the book, but then when I—in my undergrad—that’s what I remember. But when I was doing my graduate work, he kind of skipped around in the book, but he still had a syllabus that indicated what content we’d be covering on what day, and what questions we needed to answer for what day. So it was all very clear. It was just not in the same sequence as the text.

I: Did you feel that what they focused on in the content—what they thought was important, or the really big ideas that they were trying to get across to you—did you feel that what they were focusing on differed in the undergraduate class versus the River Falls graduate class? Did the focus shift in your mind at all?

R: Yeah, I think for the undergrad, they were just going through very basic stuff, and they’re going very sequential. And for the grad part, I felt they were covering—they were spending more time in areas where I felt that teachers have a hard time teaching the kids. And so I felt we spent a lot of time on certain areas of content where we needed to—where we needed a little more emphasis and we needed a little more help in maybe being more articulate or finding new demos—more demos to provide an example for certain concepts—more difficult concepts.

I: So you did feel that the focus in the graduate program was—the aim was a little bit different from what you saw in the undergraduate program?

R: Oh yeah, because I mean the graduate class was more for helping teachers be more effective, and the undergrad was more like learning basic physics (laughter) I felt.

I: As a teacher, do you feel that there should be a difference in a physics class specifically designed for an educator versus a physics class that anybody could take?

R: I think they'll be a little different. I mean I think if your students don't understand a concept then you should spend more time on it. But I think it's really difficult when you have a class of fifty or more and you don't know where they are—like you give them a test and they might not—some of them—a certain percentage of them have no clue and then some of them really do get it—I think that's really tough to really plan out how much time should be allocated for each concept because your class is so big, whereas with a grad class, it's smaller and you're expecting that these teachers have a pretty basic understanding of the concepts they are responsible to be teaching.

I: Okay. Now, this is going to be strange, because we're talking about the same individuals, but did their teaching style change when you went from the undergraduate program to the graduate program?

R: (Long pause) I—well I guess I can only—I felt like they were both very encouraging—I mean the two professors I had at River Falls for undergrad—they were both very encouraging, and they both made a lot of out of class time for questions. And I felt sort of the same way in my grad class, although—I mean you'd ask them when they had free time, but it wasn't like they had special office hours at the grad level for you to ask conceptual questions. I mean, you just kind of asked them during break time or whatever. But I felt like they offered help by having the volunteers come in and—the knowledgeable volunteers would come in, and you could ask them questions. I felt like the excitement was still there. I felt like each—between undergrad and grad—they're still excited about talking about physics and like not even the content but like something that's related to physics you can use and something like that, and like I felt like their encouragement about it was the same and their passion for teaching physics was the same as well.

I: How about their availability? You mentioned it briefly. Were they more accessible in one setting versus another?

R: I felt like we were always with them, like in the summer. So I felt that if I really had a question that I wanted to ask one of my professors, I would be able to ask them. But I felt like in the undergrad setting, you're not with them. You're only with them for an hour—however long lecture is. And there's not a lot of free time to ask questions and if you need to, you need to ask outside of class. And I felt like those professors were available outside of class. But during the summer they didn't need to have outside office hours because you're with them for like six hours of the day (laughter). So if you didn't feel like you had time, then, I don't know, you're pretty ridiculous (laughter).

I: I remember. What about the labs? The labs or investigations—did the labs seem the same in both programs, or was there a difference when you were in the laboratory from one to the other?

R: I felt like there was a huge difference. I felt like in undergrad the focus was more towards basic understanding, and I don't remember really having to do—or maybe I just didn't do the labs as well as I did in grad school. But I really learned in grad school what I needed to do to get a 10. Because it was devastating to do a twelve-page lab report and getting—you know—there's only ten points possible. And so I felt like I spent hours in grad school finishing my lab reports and just like feeling stressed, and I don't remember feeling that way in my undergrad. I felt like—not that there was a worksheet I needed to finish in order to convey my understanding, but that the lab requirements were not as intensive, I guess.

I: Do you feel like it was more a shift in your—what's the word I'm looking for—Do you feel that the reason that there was this change in attitude in the lab was more you, or more a result of a difference that they were showing you in the program?

R: I think it was—I would have done well if I felt challenged or—I don't know if it's that I didn't feel challenged—or if I didn't feel like—or I felt like what I was doing was enough—I don't know why—even the requirements were the same. I just—I kind of felt like the formats for the labs in grad school were more like for students that were taking upper level physics or AP physics and I definitely didn't feel that way in college—like it was more for getting the experience and understanding the concepts, and it wasn't so much a formalizing of your understanding I guess—I don't know.

I: And when you say formalizing your understanding, what specifically did they ask you to do in the graduate level program you're maybe alluding to was missing in the undergraduate program? How were they able to get you to formalize that understanding, or demonstrate it to them differently than what you saw as an undergrad?

R: Well, I feel like it was much more inquiry in college at the grad level. Like I had to come up with—I really had to sit down and think and analyze what the data meant, and there wasn't like a format to the analysis. Like I had to pick out specifically what I learned and what the results mean, and I had to calculate error and uncertainty of every instrument that I used and incorporate that into my results. And I don't remember doing that at the undergrad level.

I: So then, I guess related to that, the atmosphere in the classroom—How did you feel the interactions between you and the instructor, or you and your fellow students—maybe these are two separate questions—how did you feel the classroom interactions were in the undergraduate program versus what you saw in the graduate program?

R: Well I think teachers are more competitive and they want to get like—they want to be the smart kid, and I think they want to get a perfect 10/10, and I that environment where everyone is striving to do their best is definitely different than when you're taking first semester or second semester physics—general physics where the kids are at varying math skills and—I don't know—I felt like—I remember my first semester physics course, and

I remember studying really hard. I remember feeling like I was studying way more than everyone else and I felt like, “Why am I studying more—” and I would do well, but I didn’t understand why people weren’t trying to do well. I felt like people were not putting in a lot of effort and that doesn’t make you very competitive—like a competitive student, I don’t think. It wasn’t intimidating at the grad level. The teachers were really—my teachers were very helpful and collaborative, and they take ownership over making sure everyone understood and—yeah—it was a positive learning environment—a more positive learning environment than at the undergrad level.

I: So when you said at the outset that it was competitive, did you mean self-competitive, or that there was an air of competition in the graduate classroom where you felt like you had to beat the person sitting next to you?

R: I think there was like one or two people who were like, “Oh, what did you get on your lab?” But I think that for the most part they were just trying to do the best that they can, and try to get a better score than they had gotten last time.

I: Did your groups do the sharing sessions at the end of the courses?

R: Yes.

I: How do you feel those affected you—or did those affect you in terms of preparing you to do what you’re about to do this fall?

R: I thought they were amazing. I was really blown by how some people really changed their classroom into not only learning science, but doing science. And I just imagine some of these classrooms—It’s like you walk in and it’s set up for kids to see science and participate in science and some of the demos are just fantastic—what some people were able to construct—you know—this isn’t something that you buy from Carolina—these teachers constructed some of these physics apparatuses by themselves and I thought that was really cool. I think that’s a really great way of teaching—is by doing and showing and having them see.

I: Okay, great. Now, in conclusion—at least with this first part talking about the program, is there anything else you’d like to say about it—good, bad, or ugly—that maybe I didn’t ask the right question to draw out?

R: Well, I felt that the physics department was really great. I thought—you know the main thing that attracted me to the program was the fact that it had a grant associated with it and the first year, I got a telescope, I got a ton of materials for free through this grant. I was kind of sad to see this effective program to train physics teachers didn’t receive the grant the next year. And I felt like having that equipment was good enough, but I thought it was just kind of a shame that it didn’t continue on. But I thought it was really great of the professors to actually apply for these grants and effectively recruit

teachers into things that would make them interested in physics. That's how they attracted me.

I: Okay, I'm sorry, how exactly did they attract you? It was—

R: They sent out an email to the alumni I think. Like, I got an email from River Falls and they had identified that the physics department had started or they had Masters of Physics or Master's of Science Education program and it was just for physics—like I didn't get it for biology or for any of the other sciences in that Master's program. And they listed all of the classes that were going to be offered that, and they also indicated that there was a grant that they had received for that summer and that participants would receive teaching equipment and teaching materials.

I: Okay. I guess then, shifting gears, I want to find out a little bit about what you have seen in the program that you were able to carry over into your classroom. Or maybe in your case it's going to be what you think you're going to be able to carry over. We'll just kind of see what you have to say. But, you've taken several of their classes and how would you say, or in what ways have students' experiences in your class changed as a result of your participation in this graduate level program?

R: I think I've been able to play with how I organize and facilitate my labs. Because I was just—I think that the way that Larry McCall structures his lab classes is awesome. And I think that he walks a fine line between showing students what to do and why, and helping them along the way so they can—the students can actually grasp the concepts through the experiment itself, and also how to formalize their lab write-ups. Because I think that each school should have a standardized way of having the students write up their lab reports.

I: These are things that you've added to your own curriculum as a result of going through this graduate program?

R: Yeah, I mean I go through the syllabus that Larry passed out to us—the lab syllabus. I go through that with them and talk about quantitative data, qualitative data, being precise and accurate, and I talk about error, and I think those are the things that I don't think kids really think about. They just want to see the water turn red, or they want to see something explode, or something like that. But really analyzing the process and the results, I think is looking at labs in a different way—I think I've tried to incorporate into mine—into the lab portion of my class.

I: And these are things that you didn't gather from the undergraduate trip through physics?

R: No, and I've always had a hard time like really having the kids inquire, and associate that inquiry because I think kids come in with varying levels of background information,

and expecting them to make an inquiry about something they have no background knowledge on is defeating and difficult. And I have to work on that myself—like scaffolding as I’m teaching a certain concept and giving them enough secure background knowledge that they can actually come up with an educated hypothesis or prediction. It gave me something to work from when I was working with my kids on sort of structuring the lab component of my class.

I: Okay. How about the homework that you give the students? Think about what you did before, what you’re doing now after having gone through this program, and maybe even what you project to do this coming fall. Do you feel that the nature of the homework that you give your students in your physics or physical science classes has changed as a result of your participation in this program?

R: I don’t do what the program does. Are you talking about the schedule of problems—the problem sets that we had to do in physics?

I: It could be. I guess what I wanted to know—it doesn’t have to be—what I wanted to know, is do you feel that the level or type of homework that you give your students now is different or changed as a result of what you saw in the program. Not necessarily that you do exactly what they did, but did the program influence in any way the way that you design and or assign homework?

R: I think it will this upcoming year. I’ve been teaching biology and environmental science. I didn’t assign problem sets for them. I had them do pre-readings, finishing labs and lab conclusions—things like that. But I think in this upcoming physics class that I’m going to be teaching I probably will have a schedule of problem set questions for them to be working on and that I’ll go over in class.

I: Okay. So, if you can think of a couple of things—or maybe there’s nothing—but what aspects in particular of the UWRF graduate have you found it real easy to carry over into your class? You mentioned the way that you talk about and conduct laboratory experiments earlier. Is there anything else that you picked up from that program right away and said, “Yes, I can plug this into what I’m doing right now?”

R: Well, this isn’t going to be directly related, but I took my—I transferred over grad credits from [a Wisconsin university] and it was facilitated by Joe and Amy Timmerman. They had actually gone through the River Falls program, so I’m assuming that what they taught me—which was the Modeling—Modeling in physics—which is something they learned in River Falls—but I thought that program was really great, and the way that they conducted a class I thought was really great with white boarding, and collaborative work within the students. I definitely, right after that summer incorporated that right away. They gave us all the materials. They gave us white boards, and examples that we went over and over again during the summer sessions, and I just felt really comfortable with incorporating Modeling after a lab and discussing the lab results in class using white

boards, so that was a pretty effective tool. I don't know if it really is considered to be part of River Falls, but I think it kind of counts.

I: Okay. Is the Modeling technique something you plan on using with your physic class this upcoming fall?

R: Yeah. I guess—you know, I taught physics this summer during summer school, but it was only four weeks. And I definitely used whiteboards when we did labs, and the kids really liked it. It was easy for them to be proud of what they learned, and how to present results, and the fact that they understood their lab. And I didn't get too many kids that were too shy, but it was a small class though.

I: And was this one of the ELL type classes—this class?

R: It wasn't. But it was a pretty big mix. It was some kids that didn't pass—didn't receive credit over school year for physics for one reason or another. And it was also open to students for enrichment that haven't taken physics yet, but are taking summer school, because they're going to be taking it in the fall.

I: Okay, so is there anything that you saw in the River Falls graduate program that you would like to carry over into your curriculum or classroom, but you don't think you're going to be able to?

R: (Long pause) I don't know if I'm going to be able to carry over the intensity of the lab assignments—have a written lab requirement—just because—well, we might work up to it, I guess, but with my population of students being ELL, I have to see their writing capabilities, but we may modify it so that they're able to use drawings and fill in the blank formats for different components of the lab write up.

I: Okay. I'm very interested to hear how that adventure goes for you (laughter). I'll have several questions for you throughout the year, because that—I'm very, very interested to hear about how that goes, because there's not a whole lot of research on doing what you're attempting to do.

R: I know. I couldn't find—they told me I needed to find a text book, so I'm looking for ESL or ELL textbooks for physics, and they told me that the wrote biology, and that's basically it—they don't carry upper level science ELL books.

I: What textbook are you planning on using?

R: I picked out a physics book that's called "Minds on Physics" and it was developed at the University of Massachusetts, and I'm hoping that that will work out pretty well. I have really small classes—I have like 15 students in a class, and I have two sections.

I: Oh, that's nice. That's a nice number.

R: Yeah.

I: Cool. Yeah, I will definitely—throughout the school year—I'm very interested to hear how this goes for you. Are there any teaching methods or practices that you value and that you use that are not part of the River Falls program? In other words, is there anything that you do that you know that works but you never saw them do?

R: Yeah, I mean when I was there at [a] High School in [Wisconsin], we had a really great literacy coach, and he—there are a lot of in-services online, and he gave us a lot of tools and a lot of handouts to use for students to kind of practice just study skills, and even here at [my current high school], we're trying to incorporate some of the added techniques for students to be more perceptible and college bound, and I think those are really great. But I don't see a lot of time for that in the summer session. I just don't—I mean, it's pretty packed enough, that I don't really see any—I mean, that would probably just be another week or something—I don't know. I feel like most teachers would get that from just—you know—their required professional development.

I: If there was anything they could add, now that you've gone through it, if you could sit on a board of directors and recommend they add something, is there anything that comes to mind that you felt might have been missing?

R: I think most teachers actually have taught physics, so this probably wouldn't be very useful, but it would have been useful to me since I had never taught physics—but it would have been neat for a Master teacher to go through this curriculum with us so I could see through their—what activities are very successful activities that a typical physics teacher would do, what sequence do they go through, what books they use, what their outline looks like, what their overview looks like—that would have been kind of neat. But again, I don't think that would have been helpful for very many other people.

I: You'd be surprised. There were no Master teachers there—Like people who oversaw what you were doing and working with the instructors?

R: Yeah, we had two older gentlemen—they don't live in River Falls, but they come back for the summer and they served as—I guess they served as Master teachers. One of them taught college level physics, the other one taught high school physics in Shakopee or something like that.

I: Was one of them Bryce Baker?

R: Bryce, yes.

I: Okay.

R: I think I could have asked—another thing though that would have been really cool around here as a class is like, what materials would really help or are a must have because we require students to pay a lab fee—all the science classes. So teachers have a budget at my school and so as an experienced physics teacher, I think it would be really cool to know like, “What are the must-haves for lab equipment, and demo stuff?”

I: Okay, great. Now, I’m kind of going into the last part here of this. I want to ask you a couple questions about your practice in particular. And you can focus on any topic that you teach to answer these. The physical science would probably make the most sense, but when you’re working with your students and you’re going to begin a topic, how do you usually engage your students at the beginning?

R: Well, it’s really structured. I have like a pre reading. So I have them read an article, or—I either have them all read the same article, we read it out loud together, discuss it, and they do like a warm up on it—something like that, something new. Something catchy, or I pick out a bunch of articles and I have them do a jigsaw so that they all receive different information about the same topic. So they all kind of start out the unit with the same background—common background information. Sometimes I’ll start out with a demo and I’ll have them observe and infer. I always have a warm-up, and so sometimes we’ll refer to the topic we’re about to discuss.

I: Okay. Do you think prior knowledge is important when you’re getting ready to jump into something do you—how and when do you assess your students prior knowledge—what they’re bringing to the table before you dive in?

R: How do I assess their prior knowledge? At the beginning of the year, I usually do like a content inventory, but that’s more general. When I do it per unit, I really try to not assess it, because I don’t know—I don’t give them like an assessment or a test or anything like that to see what they know. I usually just try to give them information through an activity, so that they come to the table with something that they all have together that’s shared, that they have in common.

I: What’s the content inventory that you mentioned?

R: Oh the inventory. That’s just something that they’ve already had, and content-wise—content—prior knowledge, I guess—or background information that they have.

I: And this is something you give them at the beginning of the year to figure out where they’re at?

R: Oh a content—yeah—like for biology, I’ll ask questions about the topic like what is the smallest unit—if they know—they should have some life science background, because it’s part of the middle school curriculum—what is the smallest unit of life? And

I'll maybe put a graph on it and ask them to—I'll give them data, and they'll have to graph it and see they know what data goes on what axis, and how to title it, and whether they know if it should be line graph or a bar graph.

I: Okay. So, what's your method for leading your students from the familiar to the unfamiliar? When you have them someplace where they're all comfortable, what are some strategies that you rely on to lead them into unfamiliar territory?

R: I try to do demos. I try to do labs, and I'll do the lab, and then we'll discuss it. So they'll do the activity and some sort of phenomenon—what happened—and then we'll discuss it. And we'll say, "Well, why did this happen?" And I think for physics-- whenever our Master teacher—that's exactly what he does—everything—in every class, he'll do a demo, and sometimes it'll be just a piece of the demo he did the day before, and the kids will write down the wrong answer, and as they go through, they'll write down something incorrect, and he'll just go over it, and over it, and over it, because physics, I think has more misconceptions than any other science, I'm sure.

I: So what's your method since you used the "m" word, misconceptions, what's your method for addressing that? When a student writes something down that's wrong—that's obvious to you that it's wrong, but they aren't on the same page you are, what do you do to deal with that--Because yes, that does happen a lot in physics.

R: I think for physics I would do—I would show them—I would give them examples of real life observations, like, "Well then if you say that this is true, then why does this happen? Or why does this happen?" I think in biology, I have my class say that last year's teacher told them that water is blue, and I'm like, no, it's red actually. And then we—I showed them on the Internet, on a trusty website that it says red. And for physics though, I think it's more meaningful if you show them—if they see it with their eyes. And even then, it's probably not going to stick, because misconceptions seem to—they just—it's something that always will stick with them. But just kind of showing them over and over and over again in different contexts will hopefully show them that it is a myth or that it is a misconception.

I: So you feel—if I heard you correctly—did you say something to the effect that misconceptions are hard to get rid of?

R: Yes.

I: You've discovered that in the eight years or so that you've taught?

R: Yes (laughter).

I: Okay. When you are talking about something, you mentioned showing it in a variety of contexts.

R: Um-hmm.

I: How many different ways do you represent material? Like—and you can talk about your biology class—when you are talking about something and the students typically aren't getting it, on a day when a misconception is real stubborn, how many different ways have you had to present one similar topic before?

R: Probably three different ways.

I: Okay. Can you give me some examples of ways that you've done it?

R: I show them on-line simulations, I'll actually re-do the lab, or show them a component of a lab, I could show them diagrams from the test, that show a relationship or concept—they all have flash cards and they all have concepts—vocabulary concept sheets—and go over that. I would go over that with them if there's a misunderstanding.

I: Okay. Now, this is kind of more of a physics related question. One of the things I'm sure you saw as an undergraduate, and I'm really sure you saw as a graduate student is, physics sometimes is expressed in graphs, in data tables, in equations, in sentences, in paragraphs, in diagrams, and probably a few other things I hadn't thought about. Do you think that students naturally are able to translate from one representation to another—in other words, going from a graph to an equation, or an equation to a sentence—do you think it's a natural thing for a student to be able to do that?

R: No, I don't. I think that—well, from the data that I've heard—that I've seen, students have a difficult time interpreting graphs and tables and diagrams. And they have a difficult time finding relationships between variables in those contexts. I think with numbers, even more if you're not a math person. I think that just seeing numbers would be discouraging and frustrating. I think those are difficult, but I think that they're very useful, and they're very—I like looking at diagrams, and I think that if you show them how to look at it—if you show them to be comfortable with it, I think they can be extremely useful as a setting after reading through the text.

I: So is the translation from one form of data to another something you feel you're going to place a high priority on, or something that you feel you won't have to place a real high priority on?

R: I don't think transitioning from one thing to the next, and the next to the next, is very good—Or very easy for a student to do, but I think if you are trying to show a concept, and you are using a diagram as an example, and in the lab you're using an equation, I think that students should be able to try that—they should be able to do that—they should be able to transition from—I mean if it's the same concept that you're trying to show them, they should be able to go from one thing, and be able to transition to one other

thing—maybe not from another to another to another, because I think that’s extremely confusing—I could see that being extremely confusing.

I: Okay. Now, when you’re in the lab with your students—physics, physical science, biology—how does a typical investigation begin in your lab? Pick any—you know—just kind of think of one in your mind that represents the way that you normally do things. How do you typically begin a lab investigation?

R: I like to use case studies. I don’t know if that’s the most exciting thing, but when I did environmental science, and they were doing toxicity—I think it’s good for them to know why we’re doing a toxicity lab. I think it’s interesting for them to know what kind of impact toxic substances have on living things, even if it really is a small component of the environment. So I think having them read something about it even if it’s not super exciting—I mean, to me, it’s exciting, but I don’t know—reading about the Love Canal, or DDT, or whatever is exciting to them-- but you know, I like to give them an article, or give them some background information about why we’re even doing—why we’re even interested in this topic.

I: Do you normally spell out each step of your lab procedure ahead of time, or are you more of an open ended type when it comes to conducting an experiment or doing an investigation?

R: It depends on the ability level of the class. Like usually, with my AP environmental science class, I usually—I don’t read through the instructions, because they’re fine. If I’m just walking around and they have a question they’ll ask me, but usually the really don’t need much prepping or much explanation. My regular mainstream kids—they have such a hard time—I always model what to do—I never read through the whole thing, because they’re not even thinking about—they’re not even looking at me when I read through the procedure, they’re just looking at who they want to work with, and they’re looking at the materials on the front desk, and they’re thinking about what they are going to grab when I stop talking. Sometimes I draw the procedure on the board in steps, or sometimes I make them draw out each step so the first step is obtain 10 ml of whatever solution I have, and I have them draw a picture of it. And I have them do that at home, not in class. I have them do that as like a pre-lab assignment that they need to do in order to do the lab.

I: So when you said they’re looking at who they’re going to work with, do you assign the lab groups, or do you let them choose their own lab partners?

R: Sometimes I do. Sometimes—it kind of goes in waves—like two years ago, I always did lab groups. I always counted off. Sometimes, depending on the class, I let them choose their own lab groups and then if there’s a problem, I just switch from one lab group to the next.

I: Okay. When the students are gathering their data—when you’ve given them the background and sent them off to gather data, what is your role during that process? If I walked in while the students were doing a lab, what would I see you doing?

R: Well, I’m always doing something. I’m usually making sure that they’re in the right lab group. I’m usually making sure that they’re not sitting down talking to each other. I do a lot of—with my mainstream classes—I’m just making sure that they’re moving along as scheduled. We’re on block scheduling, so I feel that even though the schedule is conducive for lab because they are longer class periods, it gives them more time to be slow. And so, I’m always trying to get them going, and getting in their lab groups, getting their materials, sitting down, and working on gathering data.

I: What happens if they ask you questions about the lab? If they come up and ask you a question like, “Why is it doing it this way?” or “What’s going to happen if I do this?” How do you typically field questions in the lab?

R: If they’re asking me what would happen if I do this, then, depending on the safety, I’ll let them—I’ll tell them to do it. Or I’ll ask them, “Well, what do you think is going to happen?” And then I tell them to do it if it’s safe and not—I don’t know, some of my kids during my biology dissection, “Can I cut the head off?” No (laughter) you can’t cut the head off.

I: Are you quick to give them answers when they ask you questions?

R: Usually the conceptual questions, not so much. If it’s a question about whether they understand what to do, I usually just tell them what to do—like if they are not understanding what the procedural stuff is, then I’ll just tell them.

I: Okay. So how do they typically present their lab findings when the experiment is done? What do they do next?

R: How do they structure their lab reports?

I: Well, yeah. How do you give them a grade? What do they do at the end of the lab so that you know that they’ve met the objectives of the lab?

R: Well, there’s usually questions at the end that they need to answer in their analysis. Sometimes it depends on the activity or the lab, but sometimes, we’ll just whiteboard—whiteboard the questions, and then we’ll go around and I’ll assign each group a couple of questions to present them to the class. And then I’ll have them turn in their labs and I’ll just grade for completeness, because we went over all the answers in class. And I’ll grade harshly if they don’t answer the questions because we went over them in class. Or they’ll turn in their individual lab report and then I’ll grade the whole thing.

I: When you say turn in their individual lab report, is that one per student, or one per group?

R: One per student.

I: Okay. You gave me, I guess, a couple of different ways when you have them do this, do you ever have them get up and present anything orally?

R: Sometimes if they did a special project like if they did a modeling project or something like that—they made—an example of a—the cell cycle or they showed a picture of the components of a cell, then I'll have them go up and show their product and explain it to the class.

I: Okay. Now, your classroom—the space, the equipment, and the other resources that you have available to you—do you feel that what you have is adequate for the kinds of learning experiences that you're after for your students?

R: I do, for the classes that I teach. I don't have anything for physics next year, but one of the physics teachers is going to be teaching strictly chemistry, so I have access to all of his equipment. However, he's more lecture based than lab based, so I'm not sure really what I have access to. I need to talk to him about what he has.

I: Okay. And I'm sure you'll learn a lot here, real soon. When you assess students, you mentioned that you grade things for completion, and that you sometimes have them whiteboard things, and you look at whether or not they address the questions. What about summative assessments? Do you give a test at the end of a unit, or several tests during a unit—how do you typically handle that?

R: I usually give them a test at the end of a unit-- a shorter one. I prefer more performance-based assessments so it'll be—not a lab practical, but a lab that incorporates a lot of the concepts from that unit at the end of—and that will be worth more than the test—at the end of the unit. And then at the end of the semester, I give a cumulative final exam and a lab practical.

I: Okay. What is the percentage of your grade breakdown? Like, how much for tests, how much for labs, or do you have a different way of doing it?

R: I don't have it—I just—I don't have it organized quite like that. But I—everything is just point value. I have assignments that they do—homework assignments, and I have in class work. Class work is probably the majority of the points, and then probably assessments, and then the homework.

I: Okay. I think you're going to like this question. Do you adapt assessments in any ways for different types of learners?

R: I do—I feel like any time I grade something, that’s an assessment. And so, I feel like I am grading more heavily on performance or hands on, tactile learners, and collaboration as well. And so I feel like most students that I have are that way, because the students that I have are more of a diverse group of students than the honors track students that I don’t have, except for my AP class. I do—like some students are just like too alternative where they don’t do any homework, there’s things that you can tell they are so bright—and (inaudible)—and I try to be somewhat accommodating toward them, but at the same time, I want them to know that there’s—there is a structure to school, and—I don’t know, I sort of have trouble with that, because I think that—you know, what does a grade mean? And before students know the content, they’re just not doing the typical homework I guess to get the points for getting the grade.

I: How do you accommodate for that student that you’re talking about right now—how do you, or how have you?

R: Usually those students are very creative and they like to manipulate things, so I’ve—in the past, like one student I made him make a model of a green home, and so he incorporated, like geothermal energy, and solar paneling, and he made this model of a home that is energy efficient, and I gave him credit for that. I accepted that as points for the things that he didn’t finish.

I: So you’re open to letting them express themselves in different ways as long as you can tell that they’re meeting the standards that you set?

R: Right.

I: You’ll let them demonstrate their competency in different ways?

R: Right.

I: Okay. Now, at the end—my question reads, at the end of a physics course—but you could substitute in physical science or whatever else, what do you hope that you’ve accomplished with your students? When they walk out of your door for the last time, what do you hope to have accomplished in the time that they have spent with you?

R: Well, I hope that they’re informed citizens—that they become informed, and knowledgeable citizens and that they see concepts that they’ve learned in class—they can see them out in the real world—and they are able to make that association. And I hope that—at least for environmental science – I guess thinking about that class in particular—that they—the concepts that they have learned in class will influence decisions—the life decisions that they make. For biology I think, you know all these kids are going to have to take care of their parents someday, because they don’t speak English, so these kids are

probably translating in the hospital, and it's just be good for them to know what they are translating and how to care for their parents—and I think that's a main goal.

I: Okay. Is there anything else you'd like to say about your experiences in the River Falls graduate program at all that I still missed?

R: (Long pause) Well, I just know that I'm happy that I learned something useful and applicable to what I am doing. I know there's a lot of Master's programs that are very simple—that like can take you two summers to finish, and it's like, "Write a paper here, write a paper there," you know, I really struggled through some of the classes that I took at River Falls, but I just feel that I learned something, and that I'm going to be able to be a better teacher from that program. And that anyone that graduated from that program is going to be a better teacher and not just—they didn't just do busy work and fill out the forms and write a paper on something they already know. It's a very different program—very helpful to them.

I: Okay. And is there anything else you'd like to say in closing about your knowledge and experience as a teacher—anything else you'd like to bring up that I neglected to?

R: Just in general?

I: Ah, sure.

R: (Laughter) I don't know. I think that—I went from teaching two classes to three, and I'll be teaching a new class this year—physics—and I taught an new class last year, and I think science is changing—I mean, when I was a student, I had one biology teacher, and all he taught was biology, I always felt like—you know, when teachers teach one subject area, they are really able to—something related to that subject area—they are really able to perfect, and observe, and reflect on student learning and on content, and on their technique and stuff. And I feel like it's kind of a shame how we're being stretched out to teach all these different classes, and—but I don't know (laughter) anyway—

I: Well, I certainly appreciate you taking time out of your summer to talk to me about this, and in the not too distant future, I might be asking you for some kind of a portfolio—I don't know what I mean by that yet, but something that's going to be representative of the coursework that you give your students. And I'm not sure about this yet, but I may actually be asking if I can head out there and watch you work one of these days—you're quite a ways away from me, but I love long motorcycle trips so (laughter)—I'm not sure what my committee has planned for me, but I certainly appreciate your input and your very unique perspective—especially having been an undergraduate and a graduate with essentially the same faculty. I think that's fascinating, so I can't wait to see how what you say compares to what the others say, and I can't wait to finally get this all put together.

R: Yeah, definitely, good luck.

I: Thank you, and good luck, too. Again, your physics program for ELL students might be a hot topic of research—there might be several other people very interested in what you're trying to do out there because, as you found out, and as I found out when I was going through my lit review, there's not a whole lot of research—practical or otherwise—on trying to do this. So this is exciting—you're cutting edge!

R: (Laughter) Oh, goodness.

I: Thank you again, and if I need anything else, I will be in touch. And if you have any questions for me, you have my email, and you have my home number.

R: Okay, sure.

I: Thank you.

Interview #5 September 7, 2010

Kristi

I: All right, it is September 7th, 2010, and I am conducting interview number five for the research on the UW-River Falls physics program. Kristi, I'll just start out with the first question that I have on my list. Do you have any professional experience in fields other than teaching?

R: Only like summer jobs when I was in college, you know, receptionist, working in a warehouse—things of that sort—but nothing as another profession.

I: Okay, and how long have you been teaching?

R: This will be my eighteenth year teaching.

I: All right, since becoming a teacher, have you always taught physics, going all the way back to that first year?

R: Yes, I did. Physics was my minor. I was a math major and physics minor. And when I first started, I had two math classes and three physics classes as my assignment at the school. And this year, I have five physics classes.

I: Wow. Was that one of your primary motivations for taking that particular job? Was physics something you knew you wanted to do before you actually got your first teaching assignment?

R: No. I mean I knew I wanted to be a math teacher, not necessarily a science teacher, but that was the position that was available. Physics was my minor, but I didn't feel that I had a very strong lab background—I mean, obviously I was proficient in the math, but not in the technique of teaching science—I didn't feel strong in that—

I: Okay.

R: But—

I: Keep going.

R: But I did. That was the position that was open.

I: So it was primarily—it was more the opportunity presented itself, rather than that's what you set out to initially do?

R: Correct.

I: Okay, and you kind of answered my next question already, but maybe say a little bit more about this if you would—When you first started out as a physics teacher with the background that you had—and you said you had a minor—how well prepared did you feel for that first year going in to teach high school physics?

R: (Laughter) Not prepared at all. When I walked in they had adopted a new textbook, but it was the teacher previous to me that had left that had picked the book. But none of the books had arrived, so I started with nothing. So I was unprepared that way, because I felt like I had no materials behind me, and that I was just kind of going on the fly with everything. And then like I said, I didn't feel like I had a strong enough lab background, and so I was basically teaching the kids another math class that they found extremely boring and not helpful to them.

I: Well, once that year started and you actually were rolling—you know—maybe a couple of months into the school year—did your perception about your ability to teach change at all after you got rolling? Were there any changes—better, worse, or anything?

R: I think I got just a tad bit better at communicating some of the ideas, but it was still a daily struggle, and I was just barely ahead of the kids. I had some background knowledge, but definitely not enough to answer some of their questions—and again, truly I was teaching it like a math class.

I: Okay, so then somewhere along the line you ended up in the River Falls program. How did that happen?

R: (Long pause) Let's see. I think I got connected to SWAPT, which is the Southern Wisconsin Area Physics Teachers, out of the Madison west physics teachers group.

I: Okay.

R: Betsy Barnard, Mike Lyman, and at the time it was Dave Brownschweig too--Who was a PTRA for the River Falls program. He was an assistant, I think—at the River Falls program. So I think he talked to me about it, and about the summer program. And then he sent me information and got me involved in some of the activities that SWAPT did, or WSTA—Wisconsin Science Teachers, and different things. And I found out about the program at River Falls.

I: So, how many years had you taught physics before you entered the River Falls program?

R: (Long pause) I think I took a couple of classes just—I don't know if they had like an outreach sometime in the Madison area—maybe like Dave Brownschweig or something—because I think I took—like an outreach class or something that they had on

radiation or health effects of radiation. That was probably my third year of teaching, and then I think the next year I got into the program—so like forth or fifth year of teaching.

I: Okay, and you actually completed the program and earned the MST degree, right?

R: I did. Once I started the program, I did follow and—you know--- took a lot of classes every year, every summer. And then I got to the point where I was writing the paper, and I kind of took a year or two maybe (laughter) off—where life kind of impeded my path.

I: I understand.

R: (Laughter) With moving, getting married and having children. So I kind of lost track of where I was on my—writing my paper and things—and finishing it. So it was probably right at the end of my seven-year limit (laughter) is where I finished. In fact, I think I might have had to get an extension. I don't remember exactly, but—

I: Do you remember what year you took your last course through them?

R: (Long pause) Let's see. Maybe '99 [or] '98—I don't know. Maybe somewhere in there—I'd have to think—I can't think of right now when I was up there last.

I: But sometime in the late '90's when Craig was still running—when Craig Lawson was still running the program?

R: Yeah.

I: Okay. Now, you completed undergraduate physics—obviously a fair amount of it to get the minor in it. How—can you comment on the experience that you had in your undergraduate level physics versus the experience that you had in the River Falls graduate program that we're talking about here? Were the courses similar, or were there some differences that you'd care to comment on—just speaking about one experience versus the other?

R: Okay. The courses for the Master's, like I remember a thermodynamics course, and an astronomy course in my undergrad, and then having that in the graduate program as well—and acoustics and optics were ones that were more specialized as you get through the main crux of the physics. So I think there was a mirroring that way. What I had as an undergrad though was definitely—the emphasis was definitely on people that were going into research—were going into graduate programs in physics—were going into engineering. It was not at all (laughter) related to education or application to education. It was all geared toward research and engineering.

I: How is that different—in your mind, how—if it's geared toward research and engineering versus being geared toward education—you're making it sound like one was different than the other. How might one look as opposed to the other?

R: Well, I think at River Falls, what they did for the teacher program that we were involved in—I mean, it was much more applicable—they made more connections to what you would do in the classroom—how would you apply it—you know, just the little teaching tips that they would give in the RA sessions or the—you know—even the lab work, you kind of approached it from a different perspective—at least I did after being in the classroom, and seeing what my students had to learn, or what I wanted my students to learn—so I would approach it differently. And I just think there was more applications available to the teachers rather than in my undergraduate program.

I: Do you feel like the courses were structured similarly—like if somebody walked in and sat in on a lecture for example in the River Falls program versus sitting in on a lecture at your undergraduate program, do you think somebody coming in from the outside would notice a difference?

R: Not off the top of my head that I can recall—I mean, what Craig and Ken presented was pretty strong-based material. I mean it wasn't watered down or anything—I don't think—for us. But what we saw was physics (laughter).

I: How about the content? Do you feel like one program stressed different things in the content specifically? In one program versus another-- Did it seem like the goal of the instructor was different in one program versus another? You sort of touched on it earlier-- I just want to make sure I'm hearing you right.

R: I think Craig and Ken—definitely their emphasis was on taking it to your classroom. How can you use this? How can you make it usable for you for your students? How can you engage your students—motivate your students? How can we make more people interested in science? And so that personally was more motivating to me, and more applicable to my experience in the classroom, whereas as an undergraduate, it was—you know—they were shotgun blasting general information to try and hit all of the majors, and as a very small percentage of us were education majors in physics, we really didn't get a lot—I mean, we got information, but we didn't get application out of it.

I: Okay. What about the teaching style of the instructors? Did the instructors in one program have a different style than the others?

R: My undergrads were pretty decent and open to helping us out, and that kind of stuff-- the same with Craig and Ken and Blake and the rest that I had up at River Falls. I can't really say that there was a difference in instructors.

I: Okay. What about the size of the classes in one program versus the other?

R: I went to [a smaller state college in Wisconsin] for my undergraduate, so most of my classes were fairly small-- the same at River Falls.

I: Okay. How about—and I think you just said this about 30 seconds ago—but the accessibility and availability of the professors—was there a difference in one program versus the other?

R: No. I think they were both—the ones that I had at [a smaller state college in Wisconsin], I got to know pretty well, and the same at River Falls—very open, very helpful.

I: Okay. Now, comparing a lab experiment—I'm sure you did labs in your undergraduate physics. Would that be a fair statement?

R: Um hmm.

I: And I know you did labs at River Falls. Did they seem the same, or did the focus seem different in one versus the other?

R: No, I think the lab components were identical—like in terms of doing the optics labs, or the mechanics labs that I remember off the top of my head. I guess those are ones that I have even used in my own classroom now, because I know that it's good to prepare my students for what they might see at the college level. So I think in both regards, the undergrad and the graduate classes were the same that way. I think the emphasis—like when I did my analysis in the graduate program—obviously I had a different focus when I was looking at how I could break it down for high school kids.

I: Was that something that you were doing on your own, or did you feel that one program focused more on the importance of breaking it down for high school kids versus another—the other program?

R: I think that just kind of came—I don't remember it being emphasized at all in the program, but I just it came naturally out of (laughter) throwing thirty teachers—or however many there were of us—and then just discussing it, like—“Oh, I have this equipment,” or “Well, I don't have this, what do you think I could use instead?” Or, “I wouldn't do this part of the lab, I would do this part.” You know, it just happens when teachers get together (laughter).

I: Sure, and when you were with the undergraduate group where it was a broader spectrum of people—

R: Right. They just wanted to get through the lab and get out and go on with their day (laughter).

I: Okay. So, on a related point then—how about the classroom atmosphere—the way that the students interacted with the instructors and/or with each other? I guess that could be two separate questions. Did you feel that the interaction between—I will make it two different questions. Did you feel that the interaction between the students and the instructors was different in one program versus another?

R: In my undergraduate it was much more formal, especially in the introductory classes—the Physics 201—whatever the numbers were—but in the introductory classes, it was very formal, because there was ninety of us—or whatever—in those entry classes. But then as I got to optics, acoustics, and the more specialized topics, then you got to know the professors better, because there was only twenty of you (laughter)—a lot smaller classes. At River Falls, it was always a warm, back and forth feeling between the professors and the students where we always felt very relatable and that topics could be brought up and ideas exchanged and, you know, “What about this?” And, “Could you explain that better?” And it was very easy flowing.

I: All right. How about the interactions among the participants? Was there—did you sense a difference in attitude that way in one program versus another?

R: Oh yeah. At the graduate classes, given that we were all teachers and stuff, it was very collegial--colleague to colleague. And, you know, very much open to working together, and “Here’s my idea”, and “Here’s what I do”, and “Have you ever tried this”, and at the undergraduate, it’s—you know—you would have your study group of a few people, but a lot of times it was—you know—you weren’t interacting with very many people. If there was 90 people in the class, you maybe knew 5, whereas at River Falls, you knew everybody in the entire room (laughter) and you worked with them.

I: Okay. Is there anything else that you would like to mention—that you think is worth mentioning—about the program or your experience in it-- that I didn’t ask the right question to bring out?

R: In a positive or negative or both?

I: It doesn’t matter.

R: Okay. Positively, I would just emphasize that it was a very rewarding program for me. It has greatly enriched my teaching of science. I think it played a huge role in the increase in my enrollment in the physics program at my school. It also gave me—I think some leadership background—because I started working and maybe teaching to other adults and teachers so that led me to doing other presentations with my colleagues at the high school and other schools as well. It gave me connections in other schools, so it networked me that way. That networking is huge, because I still keep in contact with different people from the program. Negative—the only negative I can say is that I wish I

still had time to go to them (laughter). They're just so far away from me right now, and to spend the summer up there, or even two weeks of a summer, is pretty tough on my family. But I wish I could go back and do some of the classes that I haven't taken.

I: I understand. I was single when I went through a big chunk of it and like you, I have two daughters now, 4 and 2, and it would be much more difficult to make that work now. I hear you (laughter). So I'm going to switch gears a little bit and I'm going to talk a little bit now about anything that you might have been able to carry over from the program and plug into your classroom or your personal program. And so, I want to start by asking—in your mind—in what ways have your students experiences in your classes changed as a result of your participation in the UWRF program? How is what they're getting different than you maybe perceive they would have gotten if you hadn't been a part of the program?

R: I think I have a stronger connection to teaching at the high school level what an introductory student would need to be successful at the college level. By that I mean—even—you know, how you teach vectors, which is something I was doing today in class. So teaching students different ways to add and put vectors together. You know, seeing different techniques so they would see something similar to what they would see in college. Definitely a stronger lab component to my teaching, where students are getting labs that they will do again at the college level—or something very similar to them. Incorporating technology, because I think it was at River Falls where I saw the Verneir for the first time—the Verneir interfaces—and now, that's what my school uses in our science department exclusively for data collection and doing computer-based labs or calculator-based labs. I guess those would be the three things (laughter).

I: Okay. Do your students tend to spend more time working alone or more time working in a group setting? How do they typically spend their time when they are working with you?

R: It's a lot of small group interactions and sharing with a partner, and those kinds of things, and then maybe coming back to some whole group discussion. It's not a lot of "sit and get" kind of lecture stuff, but a lot of practice in the classroom, and then—where they get assistance from me. I don't know if that counts—

I: Sure. Do you feel the nature of their homework has changed at all—what you give them as homework or practice problems or however you do it—do you feel that that was impacted in any way by what you saw in your time at River Falls?

R: I don't know that it was impacted by River Falls, but our school right now is going through a transfer to standards based grading—or standards referenced grading—I guess I would call it. At the high school we're not truly standards based, it's more referenced. But anyway, they get a lot of in class practice with their formative pieces, and then their homework is only supposed to be stuff that they can do independently and that they

should be very successful at—is what we’ve been told to do with our homework, kind of. And now, their formative pieces—their homework pieces are 20% of the grade, and their summative assessments—tests and major labs—are 80% of their grade. So that has really influenced my homework this year (laughter)—more than anything else, I guess.

I: And this is new this year for you?

R: New in implementation this year at our school—it’s been a movement that’s been going through our school system probably—the very kernels of it started with different groups doing research and doing some informal training, probably in 2006. But now in 2010, this is our implementation year across the district.

I: This is off topic, but I’m curious about it. How do you feel about it at this point? What do you think?

R: I’ve been involved with it more because I—as a department chair—so I had to be part of the research groups where we were doing the study on standards based—or standards referenced grading, and so I get the philosophy. It’s just putting it into—and I think the philosophy is right, because it will make the students better learning, because it’s all about what they are learning, and removing the work ethic out of their grade, and some of those punitive things that teachers maybe put into their grades, like taking off points for late work—which—yes, you are trying to teach them a lesson about being timely with things, but should they have been penalized academically for it—you know—that separation I understand, and I agree with that philosophy. The putting it into practice—you know, how do I grade, on a 3-2-1-0 scale, or how do I feel about putting 80% of their grade on three tests that they have in a quarter? That’s a little tougher to figure out this year.

I: That’s interesting. I think a little bit later on in my study at some point I may ask you for some examples of what you are giving your kids and how you are working with them, and that will be interesting, because you’re the first person that I’ve spoken to—that’s radically different than anything I’ve heard from anybody else, so that will be interesting to see how that unfolds for you, I think.

R: I mean, a lot of the—I haven’t taken any Modeling—that’s the one—that’s the courses I wish I could take—was the Modeling stuff. I think Modeling would fit into this program where they’re getting the learning, the developing, and the inquiry, and where that’s all just practice that we do in the classroom. And then at the end you put it all together in this big picture. But I don’t have the Modeling training other than just informally what I’ve gleaned from a few other teachers and off the Internet, you know? But—I don’t know—it’s coming together—but it’s slowly coming into practice.

I: Well, it’s always an evolving process I think. I took the Modeling curriculum with Joe and Amy Timmerman back in 2000. That was my first—or 1999—and that was my first

year when I had moved over to New Berlin, and I felt like it really did a good job preparing me for my work over there, but I had a Verneir lab like you're describing. Now since I've transferred back to Richland Center-- in 2003 I came back here—and I've been trying to get them to give me some kind of a lab—period—I have that Modeling training and I did it for four years, and now I've been struggling to be able to do it because of the lab, but I would recommend—it sounds like you're—you've thought about at least looking into it—I'd recommend checking it out.

R: Yeah.

I: With all of your spare time (laughter). So you just mentioned the Modeling curriculum. Are there any other aspects of the program that you would like to carry over into your curriculum and your classroom—things that you saw, things that you did—that you would love to do in your classroom, but you haven't been able to do it yet?

R: Right now I'd really just have to say the Modeling—the Modeling part of it.

I: Okay.

R: I can't think of anything else that I haven't included—or stolen—from there (laughter).

I: Sure. Now when you went through the program, did they still—did they do something called a sharing session at the end of the classes?

R: At the end of the big ones I remember that—not the little two week ones, but I think at the end of the big ones we always did that.

I: Okay, did you ever find anything useful in those?

R: Oh yeah, yeah. I still use some of the stuff from different instructors. The kids will even ask, because they can recognize that it didn't come from me (laughter) after a while. You know how they kind of know your style (laughter)? And if I slip one of those in, they're like "What is this? You didn't come up with this! Who did you steal this from?" So yeah, there's still stuff that I use from there.

I: Okay. Are there any teaching methods or practices that you value—that you use—that you did not pick up from the River Falls program? Is there anything that you've kind of figured out in other places, or maybe figured out on your own that you know for sure you did not see when you were up there?

R: Smart boards. We have smart boards in all of our classes, and I was one of the first teachers to get one in the science department. They just kind of threw it in my room because they knew I used technology, and they said, "Figure it out, you're going to be the

expert.” So then I started—and then I would teach my other colleagues in all the departments (laughter) how to use them as we acquired more of them. And now, this year, we got funding and every science room has one—a smart board and a projector.

I: Oh, wow (genuine surprise, and a little envy).

R: We have eight rooms dedicated to science.

I: How big is your high school?

R: I think our enrollment is like 1170 students. I think somewhere around there.

I: And you said earlier you have five sections of physics?

R: Right. I have one section of AP physics and right now I think I have twelve students in there, and then I have four sections of regular physics, and those go from—I think 18 students to 26 students in those sections.

I: Okay.

R: So it’s almost 100 kids in the program.

I: And you said—now, has it always remained around that number—have you always had about five sections of physics through the years?

R: (Long pause) In the last probably ten years, I’ve either had four or five. Last year I had four. This year, I have five. Two years ago, I think I had five. It just kind of fluctuates.

I: Does it stay pretty consistent with the student enrollment? I guess what I’m wondering is—Has there been any radical changes either up or down in your numbers that you couldn’t blame on the school population? Did that make sense?

R: Right. No, It just kind of goes—you know, like I said—in cycles with the enrollment—the ups and downs.

I: Okay. And when you started out years ago, there were four or five sections of physics also?

R: There were three when I started.

I: Okay. When you begin a new topic with your students—now, you’re up in front of the class, and you’re beginning a new topic—how do you typically engage your students initially? How do you start out? And in your mind, you can pick any unit, any chapter

you want that you've got kind of on your mind. What's your game plan usually to initially engage your kids?

R: A lot of times it's a demo, or a video clip of a demo, or a video of maybe some event that they see on TV. And then, you know, can we explain it? Not like—exactly like Myth-busters, but you know, something sort of like that where they see something either in a movie, or—you know, that kind of thing. Today, I probably—today, I didn't do that. We started looking at velocity and acceleration, and I had given them—my new thing this year, with the grading changes—I want to give them a pre-test on the vocabulary terms. And so, after we looked at how they scored on their pre-test, then I just kind of start with—well, here's some definitions and—(laughter)—so I probably didn't motivate them very well today, but normally it's a demo or a video or something.

I: Okay. And the pre-test thing—my second question is how and when do you assess students' prior knowledge? Well, you answered that one pretty straightforward (laughter) with the pre-test. Is that a method that typically use, or do you have other methods for assessing prior knowledge? Is assessing prior knowledge something that you usually do in a lesson—or beginning a new unit I mean? Excuse me.

R: It's not a part of every unit that I've done. I guess I tend to do it more in the Mechanics section, just because I think that they've had that a little bit in our science curriculum, and I just kind of want to see how much they remember. When we get to the optics and the electronics and the Modern physics, I know they haven't had that anywhere (laughter) else in the curriculum, so I'm pretty much open to whatever—you know—they haven't had anything other than what they've seen in movies.

I: All right, when you figure out what your students know, how do you lead your students from what they know to what's brand new to them? How do you lead them from the familiar to the unfamiliar?

R: I guess the technique that I rely on the most is just relating it to their daily life. Like, how does it make sense to what you see every day, or how can you explain it in your everyday life?

I: Okay, and in the process of doing that, have you found that sometimes students have misconceptions or faulty reasoning, where they'll tell you something that you know clearly isn't right?

R: Um-hmm—oh yeah, definitely, it comes out with the misconceptions, and that just leads to more discussion and more investigation—more demos and all that kind of stuff. So, I think you have to give them some sort of framework though (laughter). You know if—whatever they're related to—you know, a lot it's, you know, when they are driving their car—what do they know about driving cars? What do they know about—you know, we were talking about relative motion today. I'm like, "Well, how do you know when

you pass somebody?” You know, what does relative motion mean there? So, you try to bring it back to them—teenagers are very egocentric (laughter).

I: Not in my school—naw, I’m kidding (laughter). Do you ever sometimes set up demonstrations or experiments that will create an opportunity for them to have a misconception? In other words, do you ever—and I don’t mean this in a negative way—but do you ever set traps for them to kind of catch them off guard?

R: Occasionally. It’s not a frequent practice, but there’s a couple that I have that—you know, they’re just like, “Well, that’s not possible” or “That’s not”—you know—“How can that be?”—kind of stuff. But I don’t have a lot of them.

I: All right. When you’re getting into the more mathematical aspect of a lesson, do you typically—do you introduce all of the variables at once, or do you tend to introduce them more gradually?

R: I guess more gradually. So as one builds upon another—you know—yeah—I’d say gradually.

I: Okay. And when you are covering material, you know from your training and your experience that you can use equations, you can use tables, graphs, paragraphs—and probably five other things that I haven’t mentioned yet, but there’s lots of different ways to represent material. Do you tend to favor one or two, or do you tend to use multiple representations when you are explaining a topic?

R: I definitely try to hit them—all the different styles or types of knowledge and presentations that the kids relate to. Being a math person, I probably most heavily rely on the equations and the graph, because I think the graphs tell the story so nicely (laughter). And if they can analyze a graph, they can pretty much do any kind of science --If they learn how to interpret—and that’s a crossover skill that I think all the kids should have. But I do try and have them write about science and read about science—you know—even act it out, so I do try and hit on all those learning styles.

I: And when they’re switching from, for example, from a graph, to an equation, to maybe a sentence explaining that equation—do you find that students are naturally able to translate from one form of representation to another, or do you find that that can be a bit of a challenge?

R: It’s definitely a challenge (laughter). They get into one thing, and it’s hard for them to—I don’t know if it’s the maturity or the—you know—going back to Bloom’s taxonomy—they’re just not at that level yet, and so it’s a lot of practice, and giving them a lot of practice in going back and forth between the different styles, or different types of ways to provide information. Because I know that on this first unit that we do on kinematics, they’re pretty terrible (laughter) at going back and forth. But the next time

we do it in forces, they're a little bit better. Then the next time we do it with energy they're a lot better (laughter) so I think they get better at it as they go through the year.

I: Do you feel taking the time to teach the translation from one representation to another is something important that you need to do, or do you feel more like it's just something that the kids will figure out on their own as you go through the year?

R: I guess in the past, maybe I thought, like they should know it already (laughter)—you know—why don't they know it? You know it's like, "C'mon you guys, you're already juniors and seniors, you should know this!"—You know? Can you read a graph? Can you find a slope (laughter)? But especially coming into it this year with our change in our grading philosophy and the idea that practice is for learning and then they have to be able to show what they learned at the end—and that counts so much—I think I have to do a lot more on my practice side, even though it doesn't count for very much of a grade—and I think that's what the kids have to get over too, is that, even though she's not going to count this assignment for very much, I still need to do it, and I still need to practice it, because it's for my learning. And that philosophy change is getting into the kids now that we're in our second week, but they're going to struggle with it this first quarter. It's going to be interesting then—how they do on that first test (laughter)—especially when it counts so much.

I: Sure. And, we had talked about misconceptions earlier. Do you find that—let's say that your students have a misconception about something—a common example may be asking students which object will hit the ground first, a ping-pong ball or a baseball—

R: Sure. Um-hmm.

I: Do you find that if you explain it to them once, or maybe twice, that the misconception goes away, or is it your experience that the misconceptions tend to be a little bit more robust than that?

R: I think they're a little stronger. I mean, you might be able to convince one or two kids with just an explanation or one demonstration, but most kids will just go back to that previous background knowledge and say that the heavy one is going to hit first—or whatever the misconception might be. They're going to go back to that before they really, truly change their thinking. So it does take multiple methods and multiple exposures before they change those ideas.

I: All right. Now, you did say you have the Verneir equipment—do you do labs using that equipment or other equipment with your kids? Is there a lab component in your physics class?

R: Oh yes, yeah.

I: Okay. I don't know if it's easier for you to do it by unit, or just kind of ball parking it for the entire course—but about what percentage of the time do you think your kids spend in a lab setting?

R: Oh, probably we do eight labs a quarter—maybe seven a quarter, so that would be an eighth or ninth—almost ten percent, I guess.

I: Okay. When you are doing a lab with your students—now, speaking specifically about the labs—how do your lab investigations typically begin?

R: I usually—Well, I always try to hand it out the night before so that they can—their assignment is to read it over the night before and come with questions for parts of the procedure that they don't understand, and then there are usually some pre-lab questions that they need to answer that kind of focus in their learning to the objectives or the targets. Then at the opening of class, I'll probably go over those preliminary questions with them, relate any safety issues that there would be going on, remind them of any steps—procedural steps that they might be unfamiliar with, or [that are] new to that lab, then I kind of let them go (laughter). Sometimes I pick lab groups, sometimes I let them pick—Its kind of half and half—I just see how the kids are working. Then at the end, if they finish in the class hour, we'll do a post lab there. Otherwise the next day we'll have a post lab discussion, and then usually a day or two later they'll have to turn it in.

I: Okay. When you said you discuss things with them and you just kind of let them go, with one end of the spectrum being every single step is spelled out and every single direction is given—I guess sometimes they refer to that as a cookbook lab—

R: Right.

I: --And the other end of the spectrum is being—just turning them loose and letting them go explore—Where in that continuum do you feel that your procedures to get them going—Where do you feel you fit in?

R: Given that I do quite a few of the Verneir, they're still cook-bookie. There a small percentage where I have them do more exploring stuff—more of the inquiry method or the Modeling idea where they can just kind of mess around (laughter) and see what works and what doesn't work to figure out the relationships that they're supposed to. But with the Verneir, they tend to be more cookbook.

I: Okay. Is that something—do you feel comfortable with that? Is that—do you feel that's accomplishing what you are setting out to accomplish with them?

R: (Long pause) No. I would prefer that they would get the chance to do more exploration. Given the time constraints that we sometimes have to deal with, and making sure that they get a lab experience, and at least see some stuff related to the concepts,

then—you know—you rely back on the cookbook model. I'm taking more information—you know—over the summer I did a Science and Inquiry class, and the AP College Board is doing a—like a seminar—webinar—on more open ended, or free response lab situations because that is a component of the AP test.

I: Sure. Okay. When you turn your students loose—when they're doing their investigation, what's your role during that process? What are you up to?

R: Most of the time, I'm going around monitoring and making sure students are – you know—focused on the activity, and that everyone's contributing and that they're paying attention to certain things. I'll make sure that lab safety is being taken care of, and that they are following through on what they need to do, and hopefully finish within (laughter)—or complete it in the allotted amount of time. So it's a lot of—you know—I don't know if you would call it babysitting, but that's sometimes what it feels like (laughter). It doesn't feel like it's very much instructional.

I: What do you do when they ask you questions about what they're observing?

R: You know, I'll try and turn it back to them, and relate it back to, "What are you seeing? What are—what's your observation? What is your graph telling you? What is your data telling you?" You know, and turn it back to them—if I can. Or—you know, "Why don't you talk in your lab group about what you see, and then call me back in a minute?"—You know, and have them discuss it more before they come—rely on me for the answer.

I: Okay, so when the lab is over you said you do a post lab, so how do your students typically present their findings? What's the format there?

R: Most of the time it's a written document that they turn in. It might be a formal lab report that they type up everything that they had in a lab write-up format. Sometimes it might just be answering questions at the end of the lab—analysis questions—and writing conclusion statements. In our post lab discussion, I try to hit on the major ideas, you know—"What did you learn? What did you see? What—you know—what trends did you see in your data, or in your graphs?"—You know, and try to make sure that everybody hits on the key concepts.

I: All right. Is that typically—is that the way it works all the time, or are there some labs where you do things radically different than what you just described?

R: I'm not very radical (laughter).

I: Okay (laughter).

R: They all pretty much go the same way.

I: Okay, all right. When you're looking at that lab write-up then, how do you assess that? You've kind of explained this already—but what percentage of their grade would be their lab write-ups, and what are you looking for when you are going through them?

R: Well, that's a question I have to figure out this year, because typically I just had the labs as 30 % of their grade, so about a third. This year, if I count it as formative work, the practice—which I understand it kind of falls in that area—that they're just doing it for learning—that they should get a chance to practice it again, but (laughter) there's only so much time I can hang a lab and all the lab equipment out in the room for them to do over and over and over. So some of them I think I'm going to have to call them summative—I don't know if I'll turn them into lab practicals—where they have to come in on demand and do a performance lab. So, I'm kind of toying with that idea. You know, turning some trials or some labs into practicals to have them count in weight a little bit more heavily in their grade—and then it also kind of balances out some of those tests that might sink a couple of kids' grades. This would give them maybe a little bit more foundation—especially if they're stronger in analyzing over time, rather than performing on—you know—date 15 on this test.

I: That's going to be interesting to see how that works.

R: (Laughter)

I: I'm curious to hear more about how that works as you go through it. Do you feel that you have adequate space, adequate equipment, and things like that, to be able to do what you need to do in your physics classroom?

R: Well (pause), right now I would say yes. Our school district was fortunate to pass a referendum last year—last spring. So we do have—like I said, we have smart boards in all our science classrooms—we have eight classrooms and ten teachers in our science department. We do have every room outfitted with Verneir—the Lab Pros. This year we got eight Lab Quests. We pretty much have every probe that they've ever put out (laughter).

I: Wow.

R: I mean, I'm not trying to brag, but—

I: No, I asked you the question. That's okay (laughter).

R: I do think we're in a fairly good position with technology, computers, hardware, software, and that kind of support. Facilities wise, we're not doing too badly. Our class size is creeping up a little bit—they want to put more than 26, which—you know, maybe you have more than that, and maybe 26 sounds like we're being babies, but really, we're

trying to stand pat on that because we don't want it to become a safety issue. So right now, I would say our department is very—is well supported.

I: Okay, that's great. Your administration then—do you feel that they're supportive of addressing your needs—listening to what you have to say?

R: We have a new administration. In fact, it seems like everybody's new at the administrative level. Our principal is two years in, our associate principals are two years and three years in, our Superintendent started in September, but it seems like they have backgrounds in secondary education. Our principal was a chemistry teacher the Superintendent was a math teacher at the secondary level, and a computer teacher at the secondary level. So right now, I think we're doing pretty good (laughter). They kind of know what we need and how we're going to do it, so—We've built up a pretty strong department, and our reputation in our school district that we put out strong kids that have strong science backgrounds. To brag a little bit more, about 85% of our kids do take chemistry, so they are taking three years of science, and a lot of kids do take four. But about 85% do take at least three.

I: Fantastic—no, that's good. The last little bit that I've got for you then—this may drive you nuts now, because of where you're at, but I wanted to ask a little bit about the way that you assess student work in the classroom. What are some specific kinds of formative assessment that you plan to use I guess would be the right way to frame that—When your students are still investigating a topic, what are some of the formative things that you do while they're in the midst of doing that, or that you plan to do now that you're undergoing this change?

R: Right. Right now my plan for formative is maybe having them look a little bit more at vocabulary terms so that they have a stronger understanding of just the terminology. That's what I'm using as my pre-assessment. And then to—you know—gauge what they know prior to coming to class. And then, whatever ones they get wrong on their pre-test, they have to go through a definition and creation of definitions. Other formative pieces would definitely be the math practice components—practicing lots of problem solving, equation solving. Some of the other formative would be—you know—explaining demos that were done, or quick lab activities that take less than ten minutes to perform, and those kinds of things. Not major investigations, but simple investigations.

I: All right.

R: So, that would be my formative.

I: Okay. And then the summative you said is—counts heavy. Do you envision those summative assessments looking like your old chapter tests or unit tests—?

R: No.

I: How will they look? How will the 80%-ers look do you think?

R: (Long pause) That's a good question (laughter). Right now, I'm going off of what I did on my old unit tests, which had some multiple-choice, some short answer, some—you know—explaining questions—analysis questions. So I'll probably still have a test that looks like that. I'm toying with the idea because part of the other part of our policy that administration said we needed to include and the philosophy says that you should have, is that for summative they should have a chance to retake it once. So my retake is going to be different. It's going to be addressing the same targets—learning targets, but what they have to show might look more like an essay-style test, or might be more open-ended where they have to craft their own problems, or craft a lab situation that they could use to verify or prove a concept. So—I don't know (laughter)—that's what I'm tossing around.

I: All right. In the process of doing this, do you now, or have—do you plan to or have you in the past adapted assessment in any way for different types of learners?

R: Yeah, it was more for the low level kid—you know, making accommodations in terms of allowing them to use formula sheets or formula sheets that had extra notes attached to them, or sometimes, you know, setting up problems, or assisting the students in setting up problems as they took the test. That's about the only accommodation I guess that I've made.

I: All right. Do you get a fair number of students like that in your classes?

R: No, not in physics.

I: Okay.

R: When I teach just the general science classes yeah, but not really in physics.

I: All right. By the end of your physics course, you know, let's say it's getting to be May or June, what do you hope to have accomplished with your students? At the end of the year when you look back, what is it that you're hoping that you've been able to do?

R: I guess I always hope that—you know—I've given them—you know—a different outlook on life—like, how they can see science in their everyday life, and how it applies to them in their everyday life. I hope I've motivated them to take more science—not necessarily physics, because it's not for everyone—but at least continue with something in science. And I guess I hope that they've had a little bit of fun—you know—that we've learned and had a little bit of enjoyment, too, from what we learned.

I: All right. Is there anything more that you'd like to say about your experiences in the time that you spent in the River Falls program?

R: No, I mean, it was a good time. It was very rewarding and enriching to my teaching. I appreciate what Craig and Kermit, and all the other professors—Earl Blodgett and—oh gosh, I can't even remember everybody [inaudible] you know, all that they did for us. It was a good experience in meeting all the other teachers and carrying through that network, and keeping those connections—it's been very helpful.

I: Okay. Do you think that a program designed to teach physics teachers should look a little different than a program designed to prepare people to be physicists?

R: Oh yeah (laughter). What I had in my undergrad, you know, did not prepare me for taking it into the classroom. You know, I tried to transfer over what some of my math theory did—or you know—methods of teaching math—I tried to carry that over into science, but the science methods or teaching physics methods course wasn't very helpful in my undergrad.

I: You didn't have one of those?

R: I didn't. We were supposed to have a science methods class, and then the person got sick or something, and then we never had it (laughter), so I only ever had math methods.

I: Okay. Is there anything else that you'd like to say about your experience as a physics teacher, or anything else that you feel I need to know about anything that we've talked about or otherwise?

R: Not that I can think of (laughter). I mean it's challenging, it's interesting, and every day is different. I think that's why a lot of us go into education. It's because we just enjoy making those contacts and seeing the "a-ha's" on the kids' faces or having them come back and say, "You know, you really did teach me stuff," and "I could sit through my college class, and I got an easy A because you showed me stuff," – you know when they come back and talk to you and they're... human beings (laughter) and they've matured and they appreciate you a little bit—you know—that's what you do it for.

I: Okay great. I just want to thank you again. I know it's kind of late here—at least for me anyway (laughter). I certainly appreciate you taking time out of your schedule to talk to me about this. And I will probably be in touch at some point asking you for maybe some artifacts related to what it is that you're doing—

R: Good.

I: Things that you probably haven't even made yet, but you will be—

R: Probably not (laughter).

I: Thank you very much, and have a good night.

R: All right. Thanks, bye.

I: Bye-bye.

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Dee

I: Okay, I think it should be recording now.

R: All right.

I: So, I'll start out with the first question I have for you. Do you have any professional experience in fields other than teaching? And if so, could you tell me a little about them?

R: Actually, I don't. I've always been a teacher.

I: Okay. How long have you taught?

R: This is my—I started teaching in—let's see—the fall of 2001, so it's been nine years.

I: Okay. And so straight out of college, you got a job as a teacher, and that's what you've done since?

R: Correct.

I: Tell me about what you've taught in those nine years.

R: I've taught—I have a science and math, so I've taught some of both. I've taught algebra, I've taught remedial math, I've taught chem., I've taught physical science—usually to ninth graders, I've taught general biology—let's see, what else have I taught? I think that's probably it. The big ones are physical science—I've done that the most—and then chemistry, and then some math in there, too.

I: Okay. Now have all of these been—I think – you're in Amery, right?

R: Correct.

I: Have all of these been in Amery?

R: Nope. I taught for a year in Spring Valley—over by River Falls.

I: Okay.

R: And there I taught a section of algebra, and then some chemistry.

I: So what influences led you to teaching physical science? Was that in the plan while you were going to school—or how did that come about?

R: Well, it kind of came about—I was at—my major is chemistry, and I have a math minor. So when I got out of college, I wanted to get a job anywhere. So, I was in River Falls at the time, and so I applied in Spring Valley, and they had some general science openings. So I was like, “Okay, I’ll apply for that,” and I think I had an emergency license for physical science then, and they had me teaching some chem., some regular science, and then some math, because I had a math certificate. My husband is also a teacher. He was teaching in [a city in Wisconsin], and we got engaged at that time, and we needed to be closer together. So that’s when I applied in [a nearby city in Wisconsin], and I got that job, and they needed a physical science teacher, and then a person who could teach some chemistry. So that’s kind of how I got that.

I: Is physics something that may be on the horizon for you? Where does that stand right now in your career plan and your situation?

R: Well when I started my Master’s program, there was a guy who I work with—he just retired last year—He’d been teaching there for many years, and he was the chemistry and physics teacher. And so when I started my Master’s program in physics, I envisioned that someday I would take over his classes—His physics and his chem. classes. So I knew I would have the chem. licensure, it was the physics licensure I was missing. So when I started the Master’s, that was the goal—was to get that physics license so that I could teach physics. The—subsequently in this last year, some things have changed in the district, and now they have a half time person teaching physics because—it kind of all got messed up because we didn’t get a referendum, so things have not turned out the way I had envisioned (laughter). So, in the future sometime I’d love to teach physics, but right now, I’m pretty much physical science and chemistry.

I: Okay. When you initially started out as a teacher, how well prepared do you think—How well prepared did you feel if the job would have been being a physics teacher? Back in 2001 when you were starting out, how well prepared do you think you would have been to walk in and start teaching physics if that’s the way it would have been?

R: Oh, that would have been tough (laughter). I think—my undergrad was from River Falls, and so I did have some physics as a part of my chemistry major, but going in and like teaching physics right away in 2001 on, like an emergency license, I would have been very overwhelmed I think—with just the content and trying to get the labs, and yeah—it would have been overwhelming (laughter).

I: Okay. I think you actually answered my next question, but I’m going to see. So, what led you to the UWRF Summer Physics program?

R: Well, when I first started, the classes were free. They were through grants, so they had grants where you could apply and get free credits, or—

I: When did you start?

R: I started—it's been a long process. I started—I think I started in 2002.

I: We just missed each other.

R: Yeah. Yeah I started—I took my first class in 2002 because I was getting my job in Amery and I needed some additional credits, and so that's when I found out about it and started going back. Right in there somewhere.

I: Okay. And you said initially they [the classes] were free? And—

R: Right, and then I was in the program. And I liked that it was summer only because doing classes and doing school, too, was too much for me. So I liked that it was summer only, and I could just focus on that in the summer, and do school in the fall and winter, and then—So I just kind of did it over quite a long period of time. They say it takes three years. I've been doing it—I'm still not quite done. I've got all my credits except my research project.

I: Okay, and that's something you anticipate finishing?

R: Yeah. Yeah, I want to (laughter). I kind of want to finish it this school year—Write it up so I can present it to them. I got an extension.

I: Sure.

R: So I can present it to them this summer and just finally be done with it. It's just gone on and on so long.

I: Oh sure. Well good luck with that.

R: Thanks.

I: So if you could compare—and this is going to kind of be strange—but if you could compare your undergraduate physics experience—what you were getting in a physics class as an undergraduate—to what you got in the physics classes as a UWRF Summer Physics program participant—How would you compare the two?

R: I would say that they're—they were comparable. The summer stuff—it went through—it kind of went through a lot more in a smaller chunk of time obviously, because it was only three weeks for each of the big block classes. So I didn't feel completely overwhelmed by it. I think I was well prepared from being at River-Falls initially and then going back to do the Master's thing. But it was kind of a shock to the system to look at the book and be like, “Oh my gosh, I haven't done college physics in

four years! I've got to get back into doing it again." So, I felt prepared, I guess, but still kind of rusty—yeah.

I: Did you have the same professors for the summer program that you had during your undergraduate?

R: Yes.

I: And who were some of them?

R: Eric Blaket, McCall—is it McCall—McCain?

I: Dr. McCall, yes.

R: McCall, I had both of them as undergrads. I know I had Blake for sure as an undergrad. And then, there were a few others that I didn't have but were there when I was there. Eileen was there—Korenic.

I: Yup.

R: I didn't have her as an undergrad, but I think she was there, and I had her in the Master's program. And there were a couple of like—One time I took a class and we had some guest people [that] came in to talk about Modeling physics. They came in and I was in one class with Modeling.

I: Would that have been Joe and Amy Timmerman per chance?

R: Yes. Yes. Yes.

I: Okay. Okay, great. They taught me Modeling as well.

R: Oh. Yup, yup, I can't—so it was Eric and Eileen—those are the big ones that I had and then I didn't have—there was one that was there, he retired right before I started my big chunk. It was an older gentleman.

I: Dr. -----?

R: Yeah, maybe. He would come and help us out with problems at night, but he didn't teach the classes.

I: Okay. Or it might have been—that could have been Bryce Baker too, I guess.

R: Yeah so—I know Bryce was there and then I think it was Dr. Lawson.

I: Okay great. And then, Mr. Pauls was the lab guy back when I went through.

R: Okay.

I: All right, so now, if you were a student in the undergraduate classes—the classes that you took before you graduated with your Bachelor's degree versus a student in these courses you took in the summer—were they structured exactly the same, or were there some marked differences between the two?

R: I would say the structure was almost identical. It was lecture, lecture, lecture... lab, lab, lab... lecture, lecture, lecture... and that's kind of—that's how it was with my undergrad—lectures, labs... lectures, labs.

I: Did you feel that what they focused on changed in the undergraduate versus what they were focusing--Or what they were hammering away at in the graduate program versus what they were hammering away at and stressing in the undergraduate program? Was there any difference in your mind?

R: I think that the—Not necessarily so much the lecture, but the lab I felt was a lot more—they wanted you to kind of do a lot more on your own in terms of writing up the lab reports. Like, with undergrad, they would walk you through it more, I think. The labs for the Master's stuff to me were really hard—Harder than the lecture part.

I: Okay. And then, how about, like the approachability or accessibility of the professors? You're in a unique situation because we're talking about the same professors, but did you feel like they were more accessible in one program versus another, or was there no difference?

R: I felt like they looked at you as more of a professional. It was a lot easier to talk to them in terms of questions than when I was an undergrad. And maybe it was just an age and intimidation thing, but going through the Master's, I felt more comfortable talking to them, just because I felt more on the same level--Like, we were all trying to get through it together, where in undergrad, it was more like, "Here's the stuff," and you know, I don't know if that was an age thing because in my undergrad, I think I was nineteen or twenty, so I had matured significantly. So, I don't know, I felt more comfortable—definitely—in the Master's program.

I: Okay. Is there anything else you'd like to tell me about the program—good, bad, or ugly—that maybe I wasn't able to address in this first section of this interview?

R: Is this in terms of like—What was taught? Would you like me to address some of that, or how applicable it was? Or are we going to get to that further on in the process?

I: You can address it now, and then maybe we don't have to get to it later. Whatever comes to mind that you think that I would need to know-- that you think the physics education would need to know about your experience there.

R: Okay, well I guess my big thing and the frustration I have I think may be because I spread it out so far—so many summers. And I'm so far away from River Falls. But a couple of things are—that I felt like I didn't get a lot of new science techniques—kind of stuff. Like they went through the content, content, content... notes, notes, notes... labs, labs, labs... notes, notes, notes... but they didn't like—You know that Modeling was pretty much the only one that was specifically science techniques type of stuff. Like now, I'm working with a professor at the University of Eau Claire, and he came into our school district, and they're doing things with the communities of learners, and like more teaching stuff that I wish I would have got through the Master's program, that I don't feel that I got. I feel it was a lot of content, and it was physics—a lot of good physics, but the teaching part of it, I feel I really missed out on-- Like new science specific techniques that I'm not getting-- Like we're really pushing in our district more inquiry—Like how to set up inquiry labs, and how to get the kids—Like this is the emerging push in science is all this inquiry stuff, and I never got any of that over in the Master's program. So I guess I would have liked to have seen that kind of a thing presented. Also like, especially with my end project, I'm getting a little frustrated with it because I'm so far away from River Falls. I don't feel like the project that they want me to produce is really going to help me be a better teacher. I feel like this Master's project is just, "Take the data, follow all of our steps..." and it's not really going to give me new techniques or—so that's kind of—

I: Did they choose your project or did you?

R: What?

I: Did they choose your final project or did you?

R: Well, I choose the final project, but I've gone through like four or five different possibilities with my advisor now, and things are falling through, and I can't get the data, and parents permission, and like, I don't have the students anymore, and I'm like—Because I'm so far away, I think that's another one of the major obstacles is everything has to be done by email and like connecting with them on this final project has been really tough.

I: I understand. Working on this dissertation, my university is in Montana, and so (laughter) I understand. There are definitely some challenges there. When you—well, based on your experience in the River Falls program, do you feel that that program changed in any way the way that you interact with your students in your classroom? Is there anything—Like I've got some examples—Do you feel that the way that you lecture or what you lecture about changed as a result of your exposure or time spent in that program?

R: Well, that's a tough question because I don't specifically lecture on physics content in the way that they presented it to me. There were a lot—what I use and have used is a lot of what the other teachers brought to the table. Like, I felt it was very, like a university program, here's the content at a university level, here's our labs at a university level. But what I really liked was the teachers who teach ninth graders, or eleventh graders, or eighth graders, who would bring labs and ideas to the table, and that would help me change how I was teaching—Like, this is what they do in their room—I'll try that in my room—see if it gets the same results—so, that stuff really helped me. The content itself, I felt was good for me personally. I loved learning it. But it wasn't going to help me in my room, because it was too high above where most of my students are.

I: When did you get the exposure to what the other teachers were doing—that you mentioned you found really helpful? At what point or how did that come about?

R: They did this thing that was called a sharing session. On the second to the last day, you would have to come up with some kind of a lab, a demonstration, something for like each of the big blocks—like Mechanics, and Electricity & Magnetism—you'd have to come up with activities or a lab that you do in your room that you really like, and you'd share it with the group, and then you could take that back with you to your district and use it however you wanted to. So they'd give you copies of everything so that you could use it, and they show you how to set it all up, and that I found to be really, really helpful.

I: Okay, great. So that aspect, the things you picked up from the sharing sessions, you found relatively easy to carry over into your classroom. Was there anything else that seemed like you were able to pick up from there and immediately apply into what it is that you're doing in your room with your kids?

R: No, not really. That was probably the only thing that would be immediately applicable. The rest of it was a little bit too high for the kids that I'm—For any of the kids that I'm teaching.

I: What if you were—and I'm kind of asking—this is hypothetical—What if you were the physics teacher next year... do you think that would change? Do you think your perception of what you were able to take out of there would change as a physics teacher versus a ninth grade physical science teacher, or do you think it might have still been too high?

R: I think it might have still been a little bit high. I would have had to have brought it down. It would have helped me to better understand what the book was wanting them to do. It gives me more background content that I can use to help them. But I don't think I could just take the information they gave me and use it in my room.

I: Have you ever heard of a program called Physics by Inquiry?

R: No.

I: It's a program based—and I'm kind of going off my script here right now but, it's a program based out of the University of Washington, and it's sort of like the Modeling, it's not exactly like the Modeling, but it's a program that I'm wondering if the professor that you are working with at Eau Claire has any knowledge of it. But it's based out of the University of Washington, and it's a very step by step, hands on approach to being able to learn physics and I would say a lot of the units have a lot of chemistry in them too, it's more like a physical science kind of a thing.

R: Okay.

I: But you might find that kind of interesting to look into. It's—it was something I hadn't heard about until I was working on my doctorate, but it's been around since about 1980, and it's based out of the University of Washington. A lady named Dr. Lillian McDermott has done tons of research on how to create labs and things for kids maybe more at the level that you're talking about. There's an extensive bunch of research. And it's worth checking out—you know—in all of your spare time.

R: Oh yeah (laughter). It's called Teaching Physics with Inquiry?

I: It's just "Physics by Inquiry"

R: By inquiry... okay.

I: And it's the University of Washington. And if you Google that, a million things will probably come up.

R: Okay.

I: Yeah, it's—

R: Yeah. That sounds interesting, because I'm really struggling, trying to—from the little bits and pieces that I can get from this professor—he came and did a little in-service for the science department in Amery, and I really like his ideas, but just implementing it is really hard, because it's rethinking how you present things, and it's tough with your oodles of spare time trying to find how to get everything into that kind of inquiry model.

I: Sure. So, is there anything that you do that you value, that you know that works great, that you did not pick up from the program? Are there any teaching methods that you know have been very successful for you that were not present in the Summer Physics program?

R: I guess I'm not quite sure what you are asking in that question. Are you trying to see things that I learned from other places that are helpful? Or things that I've developed on my own that are helpful?

I: Either-or. Both of those are acceptable, and maybe if they do come from multiple places, talk a little about that.

R: Okay. I guess the things I didn't get from the program are kind of like the, "How to bring it down" types of stuff. How to give them tools and things that they can use to get up to the level that you want them to be at? Just like—I don't know, I'm trying to think of an example—like in my class right now, we're talking about a factor label and dimensional analysis. And so, I create this six-step solver and I describe all of it, and give them steps, step by step, so they can get to what I want them to do. I don't know if that's what you're asking?

I: Certainly.

R: I'm kind of—

I: Certainly. No, that's great.

R: Yeah. And in terms of like the physics stuff, you know, I do some, like I'm trying to think of some things I do with my kids—We do electricity, and so I talk about circuits, and we talk about circuits, and they pretend to be the electrons, and I give them Tootsie rolls, and they walk around the circuit, and then I say, "Okay, now we're going to increase the voltage, how are you going to act if I increase the voltage? And I'm going to give you more Tootsie rolls and that means more power in the battery--" Like that kind of stuff?

I: Sure.

R: I'm trying to think of all my physics units, and what I do in those.

I: And you know, even high school seniors who are taking Calculus like stuff like that.

R: Yeah. Yeah, they do—getting up and moving around, and being able to be a part of the circuit—they like that. And like I said, I'm trying to incorporate more of the—you know—making your own labs, and like inquiry stuff like I've—every unit I try to have something like where they have to write their own procedure, determine what's the manipulated and responding variable, make a graph that looks at those things, analyze their data, and as a science department, we're trying to come up with big projects for every class that go into inquiry, like you make observations and then you have to come up with your own problem, and how you're going to solve this problem, and those kind of things that are related to the content. I guess those are the things that I've been

working on that I think are successful, that are helping our department move in the direction we want to go.

I: Excellent. That's good, that's exactly what I was looking for. Thank you. So, stepping into your classroom then, pick any topic that you want, it could be the stuff you were talking to me about earlier, or anything. How do you initially engage your students when you are starting something?

R: Well, actually that's kind of funny, because it's actually changing. When I would start a unit, typically, I would present information, and then I would have them do a lab. Like, I would do some kind of attention thing—attention grabber thing—and then I would give them notes, and have them do a lab. That's like the typical structure of a unit. But actually with this inquiry stuff that our department is pushing, I'm trying to do more of like, "Play with this, see what happens, what are the questions you come up with?" Then, run the notes off that. It's not perfect, and I'm trying the best I can to get it to where I want it to be, but that's kind of some—like kind of how it's morphing. Like, I'm pretty traditional in that I do an attention grabber, you give the notes, you do a lab. That's the unit. I'm trying to kind of play with that a little bit.

I: And it's an adjustment isn't it?

R: Yeah.

I: And that's more that Physics by Inquiry, and the Modeling also. If you remember in the Modeling, that's how they started, wasn't it?

R: Um-hmm. Yes.

I: You'd start out with an observation and then work back—it seemed to me as a teacher that they were working backwards.

R: Um-hmm.

I: Yeah. Well that's—

R: Because the way you traditionally teach is, "Here's a concept, here's a lab. Here's a concept, here's a lab." And so in my mind, I'm trying my very best to flip it and do like a lab or activity first, and they can hopefully get to what you want them to get to, and that's a transition into that inquiry stuff that I'm trying to do, but it's taking a while.

I: Sure. So, how or when do you find out what students already know? They call it prior knowledge. How—at what point in a unit and how do you find out what your kids are already bringing to the table?

R: I'm actually really bad at this. To be honest, I'm not very good at finding out prior knowledge. Every time I do a unit I always say, "Oh, I should have done a pre-test." But I never get around to making my pre-tests. So, it's something that I struggle with. Like right now, I'm teaching chem. for the first time in like four years, and I'm struggling with "what do they know?" And that's just something that I'm bad at. I just kind of dive right in, and don't really look at what they know and what they don't know. I kind of make an assumption that they don't know hardly anything—

I: (Laughter) Okay.

R: --And probably boring some of the kids who already know it. But—so that's kind of my—I don't do a very good job with that kind of answer.

I: Okay. All right, fair enough. So—and don't feel bad—(laughter)—So when you are taking students from something familiar to something unfamiliar, what do you typically do to walk them down that road?

R: Like in terms of like—

I: Well one example—

R: Like concepts or—

I: Sure. Like for instance introducing the concept of acceleration to a student. They might understand position, they might understand velocity, how do you lead them off the beaten path into acceleration—Or even maybe on a more basic level, how do you take them from something you know they are familiar with into territory where you're pretty sure they're not going to be real familiar?

R: I always try and do examples in real life. Like, let's think about this, and what's happening here? I kind of try and do more like questioning, so like, "Then what happens now? Or what happens here? Or how does this work?" To kind of get them to get them to think about the little—taking what they know, and changing it into something they don't know. That would be kind of my method for doing that.

I: Okay, great. Do you ever run into students that have misconceptions? And what I mean by that is, like for instance if you asked your kids, "If I drop a feather and a hammer, which one should hit the ground first?" Do you run into kids that automatically say that one object is going to hit the ground ahead of the other one?

R: Oh, yeah.

I: So how do you handle that? When students say something that you know is wrong, how do you—What do you do about that as a teacher when that happens?

R: I try and go back to what we've talked about, and say "Why—what you said is wrong, why is it wrong? Why is it not what you are talking about? Why is it not something that we say is true--?" So I try and work back to what we're talking about to try and get them to better perceive what's going on. Like in the feather hammer example, I would probably go back to look at a YouTube clip or something of—because I know I've seen it—of like the guy on the moon—you know, the hammer and the feather to show them that, okay there's an example—on the moon there's very little—there's no air, so see how they fall at the same rate?

I: I've never thought of that before, but I'll bet you're right. I'll bet you can see that on YouTube. Thank you. You just gave me an idea.

R: My student teacher—he—I don't know if I showed it to my class last year or if my student teacher showed it—I don't know, I can't remember, but I remember us showing it in class—like the clip of they guy on the moon. And it actually shows them both dropping at the same rate.

I: Okay. I know that film exists, I guess I just thought about being able to dial it up on YouTube. That's great.

R: I think it was YouTube. Somewhere I found the video of it, and I think it was YouTube—I don't know—I'm just thinking it's YouTube, but—

I: Do you find when—when a student has a misconception like that, or maybe a misconception about what causes the seasons, or something like that—Do you find that usually you only have to tell them once or twice, and all of a sudden they get it, and the misconception melts away—

R: No.

I: --Or do you find that those misconceptions can be frustratingly robust?

R: Oh, I think that they are robust (laughter). You can tell a kid and tell a kid, "No, that's not right," but unless they really believe it—And I don't know how you convince them of that—they don't... really... believe you (emphatic). The one I always get frustrated with when we talk about light and why light does what it does, and we start talking about water and the sunset, and the color of the sky, and all that kind of stuff, and they always will say, "Well, 'cuz my grandpa told me that the ocean is blue because it reflects off the sky." And I'm always like—NO! And I tell them and tell them and they're just like, "Oh yeah, that's what my grandpa says—that's what it is." And then I'll ask them the next year, and they're like, "Oh yeah, um-hmm, yup... that's what it is." (Laughter)... No, we went over why it's blue—no.

I: Have you found that certain exercises seem to be better at getting kids to break misconceptions, or do you think that maybe it just depends on the kid, or—Have you come up with any definitive correlations or anything in your own teaching where things—certain activities seem to work better at addressing misconceptions than other activities?

R: I guess I would say like a demonstration, or actually seeing some kind of a demonstration of that concept helps. It doesn't necessarily go the whole way, but it helps go further than just—"This is why, blah, blah, blah—explain it to you, blah, blah, blah." Because if you can show them somehow, then they are more apt to believe it I think, than if you just say it to them.

I: Okay, and when you're going through like, oh let's say you're talking about maybe a ball rolling across the floor, or a ball rolling down a ramp—In physics anyway, and I would say in physical science as well, you can represent that event by watching the event, by making a graph of the event, by using a mathematical equation for the event, by using a series of sentences to describe the event, and probably some other things too. Do you use multiple representations like that, or do just favor one or two types? What can you tell me about that?

R: I probably favor graphing. I love graphing, and I don't know if it's just a science thing, or a chemistry or a physics thing. I tend to like graphs, so I usually will have some kind of a graphic representation. And then, I like to put the mathematical equation in there. I also like to use sentences like describe. They seem to be the best with what's going on—describing it with sentences. And then—what was the other one—That you said?

I: Oh, even just one—watching the demonstration or any other thing that you can think of. There's probably some things I didn't think of.

R: Yeah. In describing an event, probably those are the big ones. The words, and then I like to put in mathematical equations, like, I put in numbers, how is this going to work? And then, I usually like to show some kind of a graph. Now my graphs are not always—especially with physical science—I don't do as much graphs, because they don't mathematically have the abstract understanding of graphs like you would as a junior or senior—like what a graph actually means—so I probably do less of that with the ninth graders, but I would do more if I had a physics class.

I: Do you ever show them how to go from a graph to an equation? Like, for example, the diagonal line on a graph is $y = mx + b$, and then you plug in the variables for y and the variables for x , do you ever do anything like that with any of your classes?

R: Well, it's funny that you should say that, because I was going to do that with my lab, because my ninth graders that I'm—we're doing about density of water—we took different amounts of water and the class found the mass and the volume and I had them

graph it. And then I was like, “Now you need to make trend lines”, and about two kids of my class were like, “What?” And then I was like, and then we’re going to find the slope, and of those two kids, only one was like, “Oh yeah, slope.” And I’m like, “Oh.” So I think with ninth graders, it’s a little bit too far mathematically for them to do the slope. Now with a physics class if I was teaching physics, I would absolutely do that. We would do slope, we would put it on Excel, I would add a trend line, we would do all that kind of stuff.

I: Do you think that it would be—Do you think being able to translate from one form of data to another—in other words, going from a graph, to an equation, to a sentence, or from a sentence, to a diagram, to a graph—Do you think being able to translate between those things is something that comes natural to most people, or do you think that that’s something that would require a lot of attention as a teacher with your kids?

R: I think it requires a lot of attention, especially if you think of the kids that are not mathematical or not science oriented. Going from a description that is just words to something that is a picture with numbers and points and—I think that’s a hard leap. It’s a leap that I feel personally that’s hard—and I don’t do it in the ninth grade because I don’t think they can make that jump developmentally—yet. That’s just me personally.

I: Do you remember when you were in college, your college professors going from graphs to equations to diagrams and such—like that—do you remember doing that?

R: I remember going—using graphs to find equations—and then like using diagrams to get data to make a graph to go to an equation. And then—I guess kind of I remember them talking about “Well what does this mean in words?—But not as much. More, undergrad is kind of the mathematical like, find the slope, what is—you know can I get—can I have a diagram and make it into a graph etc?

I: Did you that they took the time to teach you how to translate from one of those to the other, or did it feel more to you like that was something that was just assumed that you would figure out or you would come in knowing?

R: I guess I would just say that it was something they assumed you could do.

I: Okay.

R: Because I think—I felt—they didn’t teach me how to do that per se, it was kind of like a culmination of just practicing with different classes that I had, and then having math classes and trying to put them together in a way that made sense.

I: When you took the Modeling class, how did that class feel in terms of teaching you how to go from a graph to an equation to a sentence and such and such?

R: That was—I thought that was a really good example of how to do that. I really like that class looking back on it because it only taught concepts—it taught you how to teach the concepts in a way that kids at that level could understand it. I haven't used it, so I've kind of lost some of the nuances of it. But I remember liking it and going, "Oh, this is a great way to teach a concept."

I: Okay, great. So, when you're doing a lab for example, how do you typically begin when you're going to have your students do a lab exercise?

R: I guess it kind of depends on the lab exercise and where we are in the year. Because my first lab with my freshmen—It's a cookie-cutter kind of lab, where it's just like—we have—you know, you follow directions, you write down the results, but as the year progresses, we do more stuff. Like this next lab that I'm going to be doing with my ninth graders is going to—just practicing manipulated and responding variables—and we're going to do—like throwing airplanes to see how mass and volume—well, not volume I guess, but mass and distance—things that they can measure—how they affect each other in a paper airplane. And typically I would start out by giving them a problem, but because I'm trying to do more inquiry, this year, I'm going to try—and have them play with the paper airplanes first, and then I think we're going to develop a problem together to look at variables, and things like that.

I: Okay.

R: Is that kind of what you're--?

I: Yeah. And what I'm gathering I guess—if I heard you right—Sometimes—or maybe more the way you used to do it—You would give them all the information ahead of time and you would let them go and follow your directions but you're changing over more now to maybe giving fewer instructions and letting them kind of plan things more themselves. Is that kind of what I heard?

R: Yeah, that's kind of what I—I'm trying to get away from—I still use some of those cookie-cutter labs where I give you the directions and you follow it, and you write stuff down. But every unit, I try and have one that's more of an open-ended kind of a lab, where you have to write your own procedure, you have to think about how am I going to do this, how am I going to make a table to put this in? So it's not all just right there for you. That's kind of what I'm trying.

I: Sure. Well yeah, that's—that'll be kind of fun for you to compare.

R: Yeah.

I: So when the students are investigating—when they’re taking their data, when they’re setting up their experiment—what is your role at that time? How do you interact with the students when all of that is going on?

R: I typically will walk around—Do you have questions? What are you doing? That’s for my cookie-cutter labs—the ones that have the exact directions. For ones where they have to write their own directions, I require that they have me read their directions. So if they do a lab where they have to write their procedure, I require them to come and have me look at their procedure, and sign off on the procedure before they can continue. So the nice thing about that—and the kids don’t like it—but the nice thing is that I get to have one-on-one conversations with each group about, “Okay, well what are you measuring? How are you measuring that? What are you going to do? How are you going to--?” Kind of—because they’re not good at that technical kind of writing, and I have to think I kind of have to teach them how to think about technical writing in a lab report. So—I don’t know—does that answer your question? (Laughter).

I: Oh, certainly. So when a lab is done, how do your students typically present their findings?

R: I usually have them write a lab report where they have all the steps—What’s my problem, hypothesis, procedure, materials—and they go through and give me the steps.

I: Okay. Do you ever have them do it any other way?

R: I haven’t but there is I guess—we’re kind of in flux—our science department right now. Our science department is trying to do these big projects and they’re trying to create these project boards. Kind of like what you would see at a university when you have an academic day, where you are going to look at all the research that all the undergraduates are doing, and you have their posters that they make. We’re trying to do that at kind of a high school level—to present their data in that way.

I: Okay, great. How do you assess a lab report then? What do you do with that when you get it?

R: I go through each of the compartments of the lab report. Did they write their procedure? Did they take all the data? Did they make a graph? And then I just assign points beforehand to those compartments, and I go through and look and see, did they do what I am asking for—like on a graph, did they make sure the x and y axis are in the right spot with the right thing, and is it the right unit, is it labeled—or are the numbers evenly spaced—that kind of stuff.

I: Do you use a specific rubric, or are you like a total points kind of a person?

R: I'm kind of a total points kind of a – well, kind of—I don't know. What I do, is like I'll give—I'll assign certain points to each section, like this is—and they don't typically know ahead of time, it's kind of as I go—I'll say, "Okay the problem in the lab report is going to get you two points, and this gets you five," and when I hand them back, I'll say, "here's how the five points were assigned. You got one point for this, one point for that, one point for this, one point for that,"—so I don't know what that is. (Laughter).

I: Okay. Now, shifting gears a little, your classroom space—How many kids do you have in a class typically?

R: If you would have asked me before this year, it would have been usually twenty. This year I have—I think I'm at like 24. My biggest class is 27.

I: Wow.

R: Yeah, and that's my chem. sections. I've got 27 kids in my chemistry class—one of my sections of chemistry.

I: Wow.

R: It's insane.

I: How about your classroom space and your equipment and things? Do you feel that you are adequately equipped to do what you need to do?

R: I think so. I think that we are trying to move more towards electronic technology stuff. And I feel like my district is really good. We are getting interactive whiteboards through some grant money in the science department.

I: Good for you.

R: And we got some probes, which I'm really interested in using.

I: Vernier?

R: Yeah, Vernier ones.

I: Excellent.

R: Like the temperature, and like I don't teach physics, but they are used all the time in physics-- [For] force, motion, speed—all that kind of stuff.

I: Do you have a whole classroom set of those?

R: No, we don't have a classroom set. We actually have some that we got when they were selling them through some CESA thing, and so we have a few. We don't have a lot. So it's not as if a whole class can all be doing it, it's more of a demonstration tool. A lot of our physics technology is pre-dated, because the guy who taught in the spot who just retired—he'd been doing it since '68, and he basically didn't update any of his technology. (Laughter) So, we've still got the tape—the chalk tape, and – for acceleration and—

I: Spark timers! Sure.

R: So we're trying to move more towards technology.

I: Do you feel your administration is supportive in that?

R: Oh yeah, definitely.

I: Good. So now, when you're watching your kids—when they're going through a unit and you're doing all the different things you do through a unit, what are some formative things you do to try to figure out if your students are getting it?

R: Well, kind of what I do every day, is I have what is called “starters.” And so I do two questions in the morning—Like, they come in, they sit down, they write the questions and they answer the questions. And typically I use those questions as a way to see, “Are they getting it? Are the kids answering? Are they not answering? Are they just sitting there?” And if they're just sitting there, then obviously they're not understanding what's going on, so I have to go back through those questions again.

I: Okay. What about a summative assessment? Do you give unit tests or quizzes, or both, or what do you typically give them there?

R: Typically unit tests at the end of a unit.

I: All right, and how do you assign grades for a unit or a term, or whatever—How do you break your grades down?

R: Oh, like in terms of what's an A, what's a B—like that?

I: Well, like some teachers say tests are 50%, labs are 30%-- How do you do that?

R: I'm a total points person.

I: Okay.

R: I find that it confuses parents and kids less. And so, like the whole percentage thing, I was student taught with a teacher who did the percentages, and I think the parents got so confused about how the grade was calculated. And so, I've always been a total points kind of person.

I: Okay.

R: So like, I weight it though. I assign points as if it's weighted. So like tests, I'm going to have 100 points on a test, but a daily assignment might only be 10 points.

I: Okay.

R: So that's kind of how I do it, but I do a total points system.

I: Okay, sure. So, do you find that you have to adapt your assessments ever for different kinds of learners?

R: Yeah. Sometimes what I will do is—now also, I'm not very good at the adaption of the assessments—but what I'll do with kids who maybe are struggling with—who have special needs—our special ed kids—I will like modify the test or I'll let them revise the test, or they can use the notes on the test sometimes.

I: Do you ever run into—maybe—language barriers? Have you ever had to make any specific modifications for cultural or language barriers in Amery?

R: Yeah. I had a—two years—was it three years ago? I had a kid who came from Mexico. He got here on a Wednesday and was in my class on Thursday, and spoke no English. So that was a challenge, and so I had to find some resources and basically I assessed him on learning science related English words.

I: Okay.

R: Like so match—do you know what a ruler is? What's that word in Spanish? What's the word in English? Can you identify it? Can you write the English word if I showed you a ruler? That kind of stuff is what I've done. I had a couple of Arabic students who didn't speak any English. That was a challenge. Again, it was kind of a vocabulary type of a thing. We don't have an ELL person, so it's kind of all on your own.

I: How big is Amery—The high school?

R: We have about 400 kids.

I: And that's 9-12?

R: Yes.

I: So senior class about 100 students on average?

R: About 100—yeah.

I: Okay, so you're just a tiny bit smaller than us. We're about 450.

R: Okay.

I: So by the end of a physics course then, what is it that you hope to accomplish with your students (loud noise). That's me hold on a sec. Does that sound a little better?

R: Yeah, that's a little better (laughter).

I: I had the telephone sitting on top of my hot water heater when the water heater kicked on (laughter).

I: So by the end of your physical science course, what do you hope to accomplish? What are you hoping your kids walk out of the door with?

R: Well, for physical science, because it's chem.—we do chem. first semester—and physics, I'm hoping that they're prepared for their next level class-- Like, for regular chemistry or regular physics. I hope that they kind of understand what the topic is so if they want to take chemistry or if they want to take physics they know ahead of time what it's going to be about. And I think that some of the important concepts of chemistry and physics that apply to their life, I want to have them be able to do that—Like right now in physical science we're doing metric and non-metric conversions. I think being able to [loud noise—inaudible for 1 second] from one unit to another is important. So there are a few major concepts that I'd like them to maybe transfer over. But you know like that kind of conversion stuff, and also with this new inquiry—like understanding how to think like a scientist that's our emphasis. How do you look at something and think like a scientist? Do you problem solve, do you look at the variables? How could you come up with a way to examine something as a scientist?

I: All right, and how are you going to know, or how do you know whether or not your students have actually met the goals you've set for them?

R: Well, with content-type stuff, I usually do a final at the end of the year. I don't know how much that actually is helping me to determine it, because I do let them use their notes. So, I don't know if it's a test more on content or on “can you use your notes effectively.” So I kind of go round and round about giving a final. I never quite know for sure if I should do it. I've been doing it for as long as I've been teaching physical science now, but we've had some discussion about that in terms of a final exam—is it

really testing what I want it to test? And then I kind of look at – to see what they're doing in Biology, and I kind of use that as a gauge on how like, "Am I preparing them rigorously enough the next course? Are they doing okay in the next course?"--That kind of stuff.

I: All right. Is there anything more that you'd like to say about your experiences in the River Falls program?

R: I don't think so.

I: Okay. Is there anything more you'd like to say about your knowledge and experience as a physical science teacher?

R: Nope.

I: (Laughter). Okay. I certainly appreciate you taking time out of your day to talk with me about this, and I'll get this transcribed and back to you at some point in the future, and I'll give you more details about the portfolio or the student work samples and you can decide at that point in time if that's something that you want to send my way, or what, but we'll definitely communicate via email in the not too distant future.

R: Okay.

I: Thank you very much again.

R: Sounds good.

I: Have a good night.

R: Thank you. You too.

I: Bye-bye.

Interview 10 13 2010

Jim

* Note: The first two minutes of this interview the recording device malfunctioned. During that time, Josh told me that he had no professional experience other than teaching, and he was telling me about a “physics-first” philosophy that My school district has implemented in their science curriculum. When the recording device was functioning again, I asked once again about “physics-first.”

I: Well, we’ll see if it lets me now. Now it’s recording again, so you were telling me about the way your curriculum is laid out, and you do something called physics first. Can you explain that a little bit more again?

R: Sure. It was something that our school board, our administration was looking into about four years ago, I guess. And basically, there’s a lot of districts around the state and around the country that are starting to go to more of a physics first approach, which is teaching freshman level students physics, and then following that with chemistry, and then biology, and then the opportunity to take whatever they want in the advanced areas as seniors. And we decided to go forward with it, and that’s kind of how I got involved in teaching physics. There was an opening and they wanted to restructure the high school position. We’re in a small rural school, so you know basically there’s one full time math teacher, one full time science teacher, and then somebody who’s kind of 50-50, which is me now. And so, as part of restructuring that position, they decided to go with this physics first model, and so that’s what we teach now. It’s called Foundational Physics. All of our freshmen in the district take the course, and it’s worked out pretty well so far. So, you know, that was kind of when I was getting into it. My first year, I didn’t teach—my first two years actually, I didn’t teach the senior physics—the higher level physics. And so that was my sort of sole focus in the physics area. And now I have both sections, but yeah—that’s what we do here, so—

I: So how well prepared did you feel initially to teach physics?

R: Not very well prepared at all (laughter). I hadn’t taken physics—I took a physics course in college and in high school, and then one early on in college, and I hadn’t hardly thought about physics since that time, which would have been six or seven years later. I got involved, I had a lot of planning time where I had a sub, and worked with our curriculum director and our principal, sort of planning the curriculum and learning more about it because it was all new too. You know, I didn’t know much about the physics first thing, and what exactly that all entailed either. And then I got—basically I had one summer in the River Falls program, and then that fall, started teaching right away with an emergency license right off the bat. And I—to be honest with you really—was kind of going in with my—trying to keep my head above water (laughter) making sure that we were going in the right direction, but it was tough at first.

I: What led you to the River Falls program?

R: We had a couple of teachers here at My school district that had been to the program before. One who completed it right about—one of the first years they had it I believe—in the ‘80’s maybe. And he had been here a long time—taught for many years, and he went through the program—that was how he earned his physics certification. And then another teacher who came to just finish up some credits and spent a summer in the program at River Falls, too. So I knew a little bit about it through that. I spoke with both of those guys, and just sort of found out through doing a little bit of research that that was one of the—the place to go in the state as far as a physics Master’s program, so that’s the way I went.

I: Did you have physics as an undergraduate?

R: I just had one course as an undergraduate. I didn’t have a minor or anything, no.

I: If you could compare what the experience was like going through the undergraduate course versus going through the course or courses at River Falls that you took, would you say that they were similar, or would you say that there were some differences?

R: Oh, they were definitely different. The undergrad course I took was pretty much fulfilling a science requirement. My degree was in math, I was a math major, and didn’t have a minor, so that was my main focus. I took the physics to fulfill the science requirements, and it was, you know, mostly a lecture. There was a lab, of course, too, but it was a pretty typical undergrad science course I felt. You know, not all that much different than biology or chemistry in my experience anyway. The River Falls experience was a whole different deal, with—you know—I think the biggest thing was just being with colleagues the entire time. Having, you know, a room full of teachers with varying levels of experience and then I was—you know—I taught three years of middle school, had no science teaching experience at all, and we had everybody there from somebody like me who was a newbie to people who had—you know—25 years of experience and were just taking credits to learn something new, and people who were pursuing a Ph. D. and things like that, and—just being around all different types of people but all of whom who had kind of a similar goal in mind. That made it huge, because we’d all kind of help each other out, and things like that. It was much different I felt like.

I: How about the way the instructors interacted with you as the students? Did you feel like there was any difference there between the undergrad versus the River Falls experience?

R: Yeah definitely. It was much more—the instructors are much more able to be more hands on with you. I mean, we have a group—we had a group of about twenty each

summer I was there—I was there three summers and—to be around a group of about twenty and to be there every day for anywhere from three to five weeks, you really get to know them very quickly—especially in the lab setting—not even just that—in the lecture too—with homework and everything you do—I mean they are very accepting and very willing to work with you and like I said, being the new kid on the block, I needed a lot of help, and the people there were always outstanding, whereas in an undergrad situation, you know, I’m in a huge lecture with a ton of people and the lab setting is different, too, and we were in the lab every day for the whole time I was there, so—much more hands on, and much more—I mean, the men and women there—the professors will spend hours with you if you need it, and it’s really great. It’s really helpful.

I: Great. Is there anything else that you’d like to mention about the program or your experiences in it that I didn’t bring out when I was asking my questions?

R: Just the hands-on nature of it is fantastic. I learned so much that first summer about things that I can apply directly to the classroom. I mean, they have a great balance between—you know—first the content, learning about physics and all the things you need to know—that background knowledge you need to have. But then also how to bring that to my classroom and how to have students learn that from me—all the ideas—the demos, the labs, the little hints—and it helps again being in a room full of teachers when something would come up—you know, somebody would say, “I did it this way”, or “This is what I do—this is what I talk about.” Just being able to move it towards my classroom was really the whole point. I mean, that’s why I’m there, and it’s so easy to do, and so helpful that—to me, that’s the number one advantage of the program.

I: Do you feel then that the experience that your students are getting has changed as a result of your exposure to the UW-River Falls program?

R: Yeah. To say it changed would be tough because that sort of is the cornerstone of my experience anyway. I mean, I didn’t start teaching physics until after I was in that program so—

I: Fair enough.

R: I didn’t have any basis to go by. But as at the same time, I mean the things I do and the way I try to present things is very similar to my experience and I think it’s—you know—I think it’s working pretty well.

I: Okay. What things specifically, if you can think of any, have you found it really easy to carry over from their program into your classroom—[is there] anything specific that you learned from them or did in the program that you immediately saw that you could plug and play, if you will, in your own classroom [and] in your own setting?

R: A lot of the little demos, the little five-minute ways of explain—not explaining—of showing kids—you know—this is what I mean. Those little things that I picked up while I'd been there—while I was there—have been very helpful for me. I try not to do too much of the lecture format when I'm teaching, but at the same time, some of that happens, and sometimes it's helpful to—the little demos—like with—I don't know—centripetal force or something like that, where I can—I remember where we did this at River Falls, and I can show them that, or--. You know, the labs up there were fantastic. We unfortunately don't have the resources quite as much as they do, but trying to do some of the similar things that I got to do, because like I said, I didn't have a whole lot of physics background for myself, so some of my students are not all that far off of where I was in terms of knowledge of physics than when I started, so I kind of know where they're coming from a little bit. The little things that clicked for me, I try to pass along here.

I: Sure. Are there any teaching methods, or practices, or things that you value deeply that you learned that were not part of the program? Are there any tricks up your sleeve that you've learned that weren't a part of what you were exposed to at River Falls?

R: (Long pause). Boy... um... I'm sure (laughter). For me, I guess—I don't know—the interaction—dealing with kids—you know, I'm in a rural setting, and like I said, I'm teaching physics—the first couple of years anyway, it was just to freshmen, and so the base of background knowledge for them was not as deep. And I guess just being able to try to simplify things maybe a little bit more than what happened when I was sitting in a room full of teachers learning about physics. You know, there's a lot of things that are taken for granted, and rightfully so, because you're in a room with a bunch of teachers—science teachers—and people who are very experienced, whereas I'm dealing with freshmen who are right out of middle school, and – you know—so there's a lot of little things about relating to the kids that I guess I do a little bit differently. But other than that, as far as the content, a lot of what I do is pretty similar I think.

I: Okay, so let's say that you're beginning a new topic, and you can think of any topic that you like. How do you initially engage your students typically?

R: I try to start with something that I think will catch their attention—usually a short demo, or a video clip of a situation—and then asking them to analyze, “All right, what do you think is going on here?” And at the beginning of the year, that doesn't work all that well. They just say, “Well, it's a guy on a skateboard,” or it's a car rolling down a ramp, or whatever. But as we get going they kind of know where I'm coming from, so every time we start something new, I try to engage them with something that they'll find interesting. A lot of our units with the freshman are geared around sports, or around some kind of physical activities. So I try to—you know, when we're talking about acceleration, I show them a clip of a NASCAR or something, and them racing around a corner, and what's going on there, and—you know—something to get their attention and thinking about things, and to really get them going.

I: All right. At what point—or I guess I should ask it this way—Do you ever assess student's prior knowledge? When you are introducing something new, do you ever do anything to try to figure out what they already know before the lesson even starts?

R: Sometimes with vocabulary—that's one area that I like to know how much they have already coming in. I really don't do a whole lot to assess the prior knowledge. I guess the introductory activity or the demo often takes—or gives me—you know, and it's sort of an informal answer to that based on the terms that they're throwing out—the things they're saying there. But with vocabulary, sometimes that's how I start. I'll throw out a few vocabulary words, and we have different activities that we do—as far as how they process those—but otherwise, I guess not formally, I don't do a whole lot of background knowledge—no.

I: Okay. How do you lead your students from the familiar to the unfamiliar? When you are taking them from something that you've established that they know toward something that maybe you're not sure that they know—an example that comes to my mind is the concept of velocity versus acceleration.

R: How do I sort of make that leap? Is that what you are asking?

I: Yes. Yes.

R: I guess the first thing is to try to keep it—try not to make it as big of a leap as possible. If we're talking about acceleration, we should be all ready pretty versed in velocity. And so to try to relate those two as much as possible while still pointing out the differences, and the importance of them—and again, to make it familiar to them by giving them something real to hold on to—or to look at—or to—whatever. You know, to see in action this, or to feel whatever it might be. I guess that's what I try to do—Make it as familiar as possible and sometimes that's easier said than done, but—

I: Okay, great. Have you ever run into a student that maybe has a misconception? Like for example believing that a heavier object will fall faster than a lighter one? Have you ever run into students that believe the wrong thing?

R: Oh sure. Yeah, that's one that—that specific one that you mentioned—that's one that every year—I always think it's funny—I'll fill up a—take an empty water bottle and a full water bottle and ask them which one is going to hit the ground first, and I always get three different answers and—you know—one group saying it's a tie, one group saying the heavy one, one group saying the lighter one—and yeah, that happens all the time, and so there again, that's an easy way of showing them, “Look, this is kind of how it works” and then kind of going into the why part of it. But showing them that this is the case first.

I: Do you find that they let go of those misconceptions easily? Like once they see it, are all better, or do you find that those misconceptions can be kind of stubborn and robust?

R: Oh, they are definitely stubborn. (Laughter) you know a lot of kids that think they know it all, and have all the answers, and sometimes they don't want to let go of—you know, the same exact example—I'll drop the two water bottles and – you know, it'll be one of those informal things, I'll just drop them and one will hit a fraction of a second earlier—or at least they'll perceive that it did, and they'll say, “See, it was that one,” and they won't (laughter) want to necessarily let go of it. Then [they will] come up with reasons why it was a fraction of a second faster. So that's often tough to overcome, but usually, I mean you just have to kind of stick with it.

I: Okay, so when you say, “Stick with it,” What do you do with a student that seems to be clinging to a stubborn misconception?

R: Often I guess, I mean, again, the more different ways you can show a kid something, the better off—the more likely you are that one of those ways are going to click. So I try to come up with a different example—I'll always try if I can to relate it to something that I know that he might understand better. You know, if I know the kid is a hunter, then maybe I can tie it to a bullet falling before a—you know—something else, or something like that. And hopefully, you can find some other way of making the point, or proving it to them. A lot of times, you know, kids learn better from each other, so sometimes getting the kids together in groups and doing some kind of an activity or even a lab or whatever—that will get them—you know they can kind of see it and explain to each other what's going on better than I can. So, that's one thing we do a lot of—a lot of small group things, short little activities, rather than big labs. And trying to give them as much time as they can—you know—experiencing it with their hands and their eyes as much as with their ears and with me.

I: Okay. Now you had said, and you gave me some really good examples about different ways of presenting the material. You know in physics you can have demonstrations, you can have sentences, you can have graphs, you can have equations, you can have tables—all of those things. Do you—are you somebody that uses all of those different things, or are there just a few that you pretty much stick with that you feel are tried and true?

R: I think—I know what I've done the last—certainly the last year—the last couple of years—is really try just about everything. Being I still feel new to physics, you know, it's my fourth year now, but like I said, my first year, I was sort of on my own, didn't have another physics teacher even in the building to bounce things off of, so I was sort of just following the textbook that I had, the curriculum that was sort of in place for me, and realized after a year that there's a lot of other ways to do things. And so really, the last couple of years, it's been a lot of trying. You know we do graphs, we do all of those things you said—you know—more hands on, we do simulations on the computer, we'll do labs with big formal lab reports, we'll do labs with very short reports and things at the

end. I feel like I try a lot of different ways—sometimes almost too much—that it’s just—maybe need to move on sometimes and you know, hopefully that’s enough to get the kids the knowledge they need to get—you know, maybe a little bit quicker—but yeah, I try to do a lot of different things, and I’m still trying to figure out what works and what doesn’t for me, and one of the things this year is to try to nail that down and try to figure out, “Okay, this worked well, this didn’t work well,” and try to make it a little more compact for myself so that—so yeah, I definitely think I try a lot of things. You know, sometimes almost too many.

I: Do you find that—let’s say you’re going from a graph to the equation $y = mx + b$ or whatever, and then going from an equation maybe to a sentence, do you find that when you translate from one form of data to another that the students naturally pick that up, or do you find that it’s a struggle to get them to see how to translate from one representation to another?

R: I think it’s—for me, it’s usually a struggle. And again, I’m working with freshmen. Their experience with even something like $y = mx + b$, which for most physics students would be very basic, here, that’s not as basic for them. Just today actually, we were graphing—they had done two graphs, one of position versus time, and one of velocity versus time, and we were comparing the two, and trying to get them to see that the slope is equal to the velocity at that moment, and that was a big leap for them. They didn’t quite—most of the kids I don’t think quite grasped that right away, and that was a big leap. So to go from seeing a car roll across the floor to okay now it’s on paper on the graph, and okay great, I made a graph, but what does it really mean? That’s a big leap for them. Yeah, it is tough to bounce from one thing the other, and to get them to make all of those connections, that is tough for me.

I: Do you feel in your undergraduate program that your professors took the time to teach you how to translate from one form of data to another, or do you feel that they just assumed that that was something you knew how to do?

R: I think that was more of an assumption that was made. I don’t feel like I had a lot of instruction on that.

I: How about at River Falls?

R: Much more clear. For one, I think there’s a little bit more time, especially in the lab setting, to get help with analysis and things like that. You know, I spent a lot of those lab days where you’re supposed to start at 1:00 and then set up from one to four—I was there from five to six a lot of times (laughter).

I: I remember.

R: Yup, I'm sure. And you know, it gets to be a long day, but at the same time, I mean I always came out feeling like I knew it, and for me, that was big. And a lot of that extra time was, "Okay, I need somebody to explain to me why we graphed this, what am I looking at here, what is the slope, what is the line, what do those things mean?" And that was much easier for me to pick up when I had the three or four guys that were there to help me with it. Yeah, that was—much more access to that type of help specifically.

I: So when you do a lab with your students or some sort of an investigation, how does that typically begin?

R: Usually it begins with sort of a basic situation—a basic question, and then the students doing a lot of the investigation on their own. Sometimes I'll have certain steps for them to follow, but for the most part, they're kind of able to—I give them a general case, I give them the materials, and I explain kind of what I want them to find, and I—it's a lot of an inquiry thing, where they're trying to find out for themselves. Obviously there's help. One of the physics classes I team teach and I have another teacher with me, so that's a big help, especially in the lab—making sure kids are [heading] in the right direction. With my seniors, I'm using a Modeling approach, and so there, it's very—they're given a situation and they're told after discussion with the class what they need to find, and they're pretty much on their own from that point on. And so, even with the freshmen, I try to go as little into it ahead of time as I can, and let them learn for themselves what they're supposed to be finding.

I: So while they're doing that, what's your role? While the students are gathering data, or conducting an investigation, what would I see you doing during that time?

R: Normally I'm going group to group just kind of supervising. It's hard not to—sometimes I want them to make mistakes, and I want them to try something and see that it doesn't work—[but] it's hard to stand there and watch them not always do what they're supposed to be doing, but I'm going group to group, I'm answering questions, I'm making sure they're on task, I'm making sure they're collecting—You know, usually they're responsible for collecting their own data, and after a while, they understand that there are very few things—you know, if there's something they can take away from a lab, they need to collect that data, and usually they pick up on that. But at the beginning of the year especially, it's a lot of, "Hey, did you—" and I'll walk over and look and say, "Hey did you—how did you measure this? Or why didn't you measure that? Maybe you should."--Those sorts of things. More of just a "I'm here to help if you need me, but if you're okay, then do your thing and then when we get back as a whole group, then it's more, "Okay, this is what you should have done, and this is what you should found," and that sort of thing.

I: How do the students typically present their findings to you?

R: With my older groups, they have lab reports—there's a rubric that they follow and they—there's always a graph, there's pretty much always an equation or multiple equations usually, and multiple graphs. But they have a format that they follow. With the freshmen, I do a lot more sort of informal things. So they'll—typically after an activity, I'll have a short—some type of a worksheet or a pro—not a problem set, but some type of an activity where they're just answering a—you know, some, like what did you find here? What did you find here? --Sort of basic things at the beginning. And then I sort of lead them more towards the answer than I do with the older kids. You know, the older kids draw their own conclusions and put them in a lab report. With the freshmen, I sort of ask questions that lead them in the right direction. So they'll turn in a ten-question worksheet on velocity, or whatever it might be. That's typically how I do it with them.

I: Are they always written reports, or do you ever them present orally, or do a power point, or anything other than a standard report?

R: The older group especially—we present a lot on whiteboards. I have I think 24 mini whiteboards that they can put their findings on and so, they'll put their findings on there, they'll come up front—basically they'll sketch their graph, they'll explain what the graph meant, a little bit about what data they collected—So we do some of the oral presentations. With the younger group, a lot of times what I'll do is I'll take—if we have eight lab groups, I'll take—just shuffle those groups around and create eight new groups, and so each student will be new with two other students in a different group and then they'll compare their findings with each other. So that's an oral way of doing it in a smaller setting. But normally—Normally, I would say for the most part, their findings are turned in in a written format.

I: All right. What's your classroom like? Do you feel like you have enough room? Do you feel like you have enough equipment? Maybe [tell me] a little bit about your class size. How does all that play into what you're trying to do?

R: It's a struggle. I mentioned earlier how we are restructuring the entire science program, and when I came in, they also hired a—their other science teacher is a brand new hire also, so we had two brand new teachers—which is for us the entire science department (laughter). And a lot of old and outdated equipment and damaged equipment that never got replaced and—you know, we spent a lot of time and stuff getting old chemicals and stuff out of the lab, and a lot of just junk that has been gone. And so we're slowly trying to rebuild our supply here and sort of get caught up technology-wise. I mean, at River Falls, every lab we did was using the Vernier LabPro and Logger Pro stuff, and that stuff is great. And just last year, we ordered our kind of first bunch of that stuff, and I hope to build that up slowly over the years here, but as far as getting materials and stuff for labs, that's been tough. I have plenty of space. My class sizes are around twenty for the younger groups and about fifteen for the older groups, so it's not terribly high. And like I said, I team teach one of those too, so that helps. But the equipment is

something that is sort of an ongoing thing with us, and it's been—it's made it a little tougher to do exactly what I want to do, but it's getting better I guess.

I: Do you feel your administration is supportive in your trying to acquire this new equipment?

R: Yes. They have been. I mean they understand when we made this switch in our curriculum that there was going to be a cost to it, and that things were going to need to be—you know money was going to need to be spent a little bit. And you know, that's not easy now, so obviously there's a little bit to that, but at the same time, they've committed to making this work, and we're I think the only school in our area that really does a freshmen physics class. So they've been very supportive as far as, really, everything. And any time I tell them I need something, it's for the most part—they've been very helpful in making sure we can get that.

I: Great. So looking at the way you assess, do you—What kind of formative assessment do you use with your students while they're still working their way through a lesson?

R: I have a—Well, one of the big things that's helped me is our special ed department. I've team taught every year I've had this. I've team taught with one of the special ed teachers. And you know, they have a ton of just different—graphic organizers, or little activities that can take five minutes at the end of class that we can do to just assess what we learned that day, and what we learned yesterday. And so—not every day, but usually a couple of days a week there will be a short little something—you know it will be—I don't know, we have so many different ones, but you know, something where they're writing down two things that they learned today, and one question they have for tomorrow, or—things like that—just little things that I can collect, take a quick glance at—look at the questions—Okay, seems like half the kids are asking about this, I'd better make sure I touch on that tomorrow—and those sorts of things. You know, we've done a lot of that, and again, it's helped having another teacher in the classroom just to be able to manage that—to be able to go through all of that with all of the—just the daily assignments and those things. Sometimes that is something that slips—you know, finding out what they learned that day, and so, you know, having somebody else say, “Hey, we should double check on this,” – that's been a big help for me, too.

I: Okay. So what about summative assessments then? How do you wrap a unit up, or what have you?

R: For the most part, it's—I have a unit test at the end of every unit that I've basically written myself, and obviously modified every year. That's pretty much how I wrap it up. Usually it will be a review and that. Sometimes—you know, there's a couple of units where—I'm a big fan of the PHET website at Colorado—the simulations, so a lot of times, I'll finish with one of those. You know, because our resources are limited sometimes anyway, and to be able to—you know if we're talking about projectile motion,

I can draw the pictures and show them all the clips, and—you know—throw things off the roof. But when I—you know, when we can show it to them on there, and put numbers to it—Sometimes I'll finish a unit with something like that, so that it kind of, hopefully, sort of finalizes what we learned, and we realize the numbers we're getting are the same as what we should have gotten when we did it by hand—and all of those things. So sometimes I throw something like that in at the end, but for the most part, it's a unit test, and then we move on.

I: Okay. How do you assign grades? What counts for what? Do you do percentages or total points or—what's your system?

R: I've changed that every year, too (laughter). So I'm not sure that I have a solid 100% system yet. With my seniors, I do a total points system. Basically what it works out to is lab reports end up being about 20% or so, homework ends up being about, anywhere from 30% to 50%, and then the tests are the other 30% to 50%, is about what it ends up being. With the freshmen, I have a – this year, I have a scale. I think my tests are—tests and quizzes—and sometimes I'll have like a worksheet that I'll say, "This is a take home quiz"—it's basically a worksheet, but—They'll have—I think that's 50%, my homework is 35%, and my lab and activity write-ups are 15%. So I—like I said, I've changed it just about every year, so I'm still trying to find what works for me.

I: Okay.

R: That's what I have right now.

I: Do you adapt assessments in any way for different types of learners? And if so, could you tell me about that?

R: Yeah, that's been one of the big goals of ours here as a district as a whole, and again, we're a small district, and one of the things that we strive for is 100% inclusion of all of our students. And so I think out of the freshmen there's only one or two freshmen in our district that don't have my class—that are pulled out for a separate science class. So there's a lot of modifying activities—you know, taking a concept and saying, "Okay, what does this student really need to know?" I've had autistic students and things before and you know, done a lot of modification. And like I said, it's been a help, because I've had a special ed teacher with me for at least one section of physics every year. I'll be honest, a lot of that falls on them, but it's something that we're constantly doing. And often what works for those students works very well for the other students, and even at the start of the year, you know, going through basic metric conversions—my colleague had a different chart on a different sheet of paper that for whatever reason the kids thought was 100 times better than the one I gave them (laughter). So you know, she was able to pass that along, and it not only worked for the four kids that she meant to pass it on for, but you know, the rest of the class ended up liking it too, so that's something we're always trying to do.

I: Nice.

R: And it's easier sometimes with certain things than others, but yeah, it's a constant battle for us.

I: Okay. So by the end of a physics course, what do you hope to accomplish with your students?

R: I always want them to really—maybe it's not this simple—but I always want them to sort of want to come back. I want them to think that physics is fun—it's interesting—that they can learn a lot and still have some fun at the same time. That it applies to everything they do their everyday life—that's what physics is. It's the motion and the way things work in their everyday life, and I want them to realize that—to be able—and sometimes that's why I try to always bring things back to something that's happening. You know, when the Olympics were going on, we talked a lot about the Olympics and things—the Winter Olympics last year, and how that is physics related. And so to make them realize that this isn't just a class that you take, and whatever—you know, you roll balls down ramps and whatever you do in physics—that they—that it really does apply to what they're doing, and it has a purpose, and I hope that's one thing that they realize when they're done.

I: Great. So is there anything more you'd like to say about your experiences in the River Falls program?

R: Well, I would recommend it to anybody. Like I said, it has a little bit of everything. It's content rich, and the men and women that are there are very knowledgeable about physics and very passionate about it. And so, if you just need to learn more about physics, that's a great way to do it. If you want to learn more about how to apply it to your classroom, it's a great way to do that. It's a great way to meet other physics teachers, to be able to network that way. It's run—like the labs and things are—you're held to a high standard—you know, expectations are high as far as what they expect you to be able to do before they let you out of there, and so—but at the same time, they're more than willing to help, and you really learn a lot. So I—it was a really good experience for me, and I'd recommend it to anybody.

I: Did you finish? Did you get your MSE?

R: I'm finishing right now actually. I should be done in December.

I: Congratulations.

R: Thanks.

I: Is there anything more you'd like to say about your knowledge and experience as a physics teacher in general?

R: Oh, boy. Just that I think—one of the things I like about it is it seems like there's always something new, and you know, I'm only four years into it, so maybe I'm still learning the new things. But it seems like there's new ways of doing things. Things are changing and technology is getting better, and that I really like—I mean it was really nice for me—it has been really nice for me to be able to, you know, take on something new, and—you know, professionally, it's been a really good thing for me—you know to constantly just be challenged—to find new and better things—it's been good.

I: Excellent. Well I want to thank you for taking a little time out of your afternoon to talk to me, and I will probably be in touch in the not too distant future, and maybe ask you a couple of other things—I'll be in touch via email. But I just want to thank you for your insights and time.

R: Sure. You bet.

I: Thanks, and congratulations on completing the program.

R: All right, thanks Randy.

I: I'll be in touch. Have a good day.

R: All right, you too.

APPENDIX J

CASE PARTICIPANT PORTFOLIO INVITATION

Greetings UWRF case study participant,

I hope you are off to a strong start with your students this school year. So far, you have completed a survey, which revealed demographic data, as well as some of your beliefs about teaching, and your feedback about your experience in the UWRF Summer Physics program.

You also participated in a telephone interview where you provided additional information about your time at UWRF, the practices they engaged in as instructors, and what you have been able to (or not been able to) carry over into your classrooms.

I am now asking you to create a single lesson portfolio to provide a snapshot into your actual teaching practice.

The first sheet asks for an introduction to the lesson, the anticipated goals, and the connection to River Falls (if applicable).

The second sheet is to accompany a sample of student work. You may cover the name of the student if you wish.

Next, you will find a short summary of the Five Principles for effective physics teaching developed by E.F. Redish. Each principle is initially defined, with several indicators occurring after each definition. You will use these as a guideline for completing the next two forms.

The next form asks you to reflect on which principles you focused on as you developed the lesson, and which principles you focused on as you actually taught the lesson.

The final form asks you to identify how each of the five principles were addressed during your training as a part of the UWRF Summer Physics program.

Please feel free to attach additional sheets of paper as needed. Please feel free to address both strengths and weaknesses of the program, the lesson, the student work samples etc... the more you share, the richer the data analysis will be down the road.

I would like to collect these samples before Christmas break if at all possible. You can email me the material, or send it in the self-addressed stamped envelope that I have sent to each of you. If you have any questions, please contact me at ketr@richland.k12.wi.us or at 608-647-9818.

Thank you very much for your time, at the conclusion of this study, each of you will receive a cash stipend for your contribution in the amount of \$75. I do not expect you to work for free ☺

Sincerely,
Randall (Randy) Ketola

Instructional Materials Cover Sheet

(Use additional sheets as necessary)

1. Please identify:
 - a. The level of the course (Physical Science, Physics, Honors Physics, AP Physics, etc). _____
 - b. The grade level(s) in the classroom. _____
 - c. Average class size. _____
2. Please describe the lesson being taught including what you did and what the students did.
3. State the intended goals, objectives, or intended outcomes of the lesson.
4. Describe how this lesson can be connected to your experience in the UWRF Summer Physics Program. (If applicable, include any UWRF strategies that supported your own learning as a student, which you now include in instruction for your own students' benefit).

- # Student Work Sample Cover Page

Redish's Five Principles

1. <u>The Constructivist Principle</u> – <i>Individuals build their knowledge by making connections to existing knowledge; they use this knowledge by productively creating a response to the information they receive.*</i> Sample Indicators: -- The teacher values student input, and uses correct aspects of their pre-established mental models as starting points to build bridges to new material. -- Students search for patterns or relationships in their data or observations. -- Students explain what they are observing or discovering in their own words. -- The teacher views students as thinkers with emerging theories about the world, not as empty vessels or as blank slates
2. <u>The Context Principle</u>: -- <i>New information should always be presented in a context that is familiar to the student, and that context should be established first. What the student is able to construct depends on how what we give them interacts with what they already have.</i> Sample Indicators: -- The teacher realizes the importance of simplifying contexts at times to remove distracting information, particularly when students are first exposed to the material. -- The teacher trains students to recognize what is relevant and what is a distraction for a particular situation. -- The teacher selects contexts that are familiar enough that students can easily make connections. -- The teacher attempts to select contexts that will engage and interest the students whenever possible.
3. <u>The Change Principle</u>: <i>“It is reasonably easy to learn something that matches or extends an existing schema, but changing a well- established schema substantially is difficult.”**</i> Sample Indicators: -- The teacher uses multiple representations such as written words, spoken words, tables, graphs, equations, diagrams, or others to present unfamiliar material to the students. -- The teacher teaches the students how to translate from one form of data to another (for example, from a graph to an equation). -- The teacher uses hands-on, real-life examples to force a student to come to terms with a misconception.
4. <u>The Individuality Principle</u>: -- <i>Each student has a unique approach to learning.</i> Sample Indicators: -- The teacher uses strategies in their teaching to address multiple intelligence types such as linguistic, logical-mathematical, spatial, musical, interpersonal, intrapersonal, body-kinesthetic, natural, or other. -- This teacher modifies lessons specifically to accommodate students of cultures different from the dominant culture. -- This teacher modifies their lessons specifically to accommodate students with special

** Redish, 2002, p.33

1. Reflecting back on the lesson that you chose for your portfolio entry and your participation in the UWRF Summer Physics Program, which of the aforementioned five principle(s) for effective physics teaching had the greatest influence on the design and development of the chosen lesson?

2. Reflecting back on your teaching of this lesson and your participation in the UWRF Summer Physics program, which of the aforementioned five principles had the greatest influence on your actual teaching of the lesson?

3. What other influences, perhaps unrelated to your experiences at UWRF, affected the lesson design and implementation?

Professional Learning Reflection

In what ways, if any, were each of the five principles demonstrated by UWRF in the Summer Physics Program? Give specific examples where applicable. Use additional sheets as necessary.

- 1. The Constructivist Principle**

- 2. The Context Principle**

- 3. The Change Principle**

4. The Individuality Principle

5. The Social Learning Principle

APPENDIX K

EXIT SURVEY DATA FROM UWRF PARTICIPANTS AT
THE CONCLUSION OF SUMMER COURSEWORK

Exit Survey Data
 UWRF Summer Physics
 PHYS 701: Electricity and Magnetism for Secondary School Teachers
 Summer 2006

Item	Choices	N	%	Average	σ
Lecture content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 3 12 10 0	0 3.8 11.5 46.2 38.5 	4.19	0.80
Lab content/design	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 5 8 13 0	0 0 19.2 30.8 50.0 0	4.37	0.79
Afternoon (alternate lab day) activity content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 5 14 6 0	0 3.8 19.2 53.8 23.1 0	3.98	0.78
Share session	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 10 15 0	0 0 3.8 38.5 57.7 0	4.56	0.58
Course format	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 12 13 0	0 0 3.8 46.2 50.0 0	4.46	0.58
Getting equipment for my classroom	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 2 18 5	0 0 3.8 7.7 69.2 19.2	4.81	0.51

Evening problem sessions	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	1 1 1 5 6 12	3.8 3.8 3.8 19.2 23.1 46.2	4.00	1.24
Course organization	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 7 17 0	0 0 7.7 26.9 65.4 0	4.58	0.64
Lecture instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 6 18 0	0 0 7.7 23.1 69.2 0	4.62	
Lecture instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 4 20 0	0 0 7.7 15.4 76.9 0	4.69	
Lab instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 6 18 0	0 0 7.7 23.1 69.2 0	4.62	
Lab instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 5 20 0	0 0 3.8 19.2 76.9 0	4.73	
Course meeting your needs/wants	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 3 12 11 0	0 0 11.5 46.2 42.3 0	4.32	

Ease of registration	1: Poor 2: 3: 4: 5: Excellent No Ans	1 3 5 5 12 0	3.8 11.5 19.2 19.2 46.2 0	3.92
Ease of getting housing/food information	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 8 5 11	0 0 7.7 30.8 19.2 42.3	4.20
I took this class because (check all that apply)	Personal understanding/interest Teaching certification Understanding of content to aid teaching Continuing education to maintain licensure Progress toward Master's degree Salary progress Other No Answer	25/26 9/26 21/26 8/26 22/26 15/26 1/26 0	96.2 34.6 80.8 30.8 84.6 57.7 3.8 0	

Exit Survey Data

UWRF Summer Physics

PHYS 718: Astrophysics for Secondary School Teachers

Summer 2007

Item	Choices	N	%	Average	σ
Course content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 2 12 10 0	0 0 8.3 50.0 41.7 0	4.33	0.64
Problem set	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 4 13 7 0	0 0 16.7 54.2 29.2 0	4.13	0.68
Lecture format (outline form)	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 2 3 7 12 0	0 8.3 12.5 29.2 50.0 0	4.21	0.98

Class activities for your understanding	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	1 0 1 10 8 0	4.2 0 4.2 41.7 33.3 0	4.33	0.92
Class activities for use with your students	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 2 13 8 0	0 4.2 8.3 54.2 33.3 0	4.17	0.76
1-week course time frame	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 2 5 16 0	0 4.2 8.3 20.8 66.7 0	4.50	0.83
Meeting your needs/wants	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 2 8 13 0	0 4.2 8.3 33.3 54.2 0	4.38	0.82
Course organization	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 7 16 0	0 0 4.2 29.2 66.7 0	4.63	
Instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 7 16 0	0 0 4.2 29.2 66.7 0	4.63	
Instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 1 21 0	0 0 8.3 4.2 87.5 0	4.79	

Course meeting your needs/wants	1: Poor 2: 3: 4: 5: Excellent No Ans	0 1 2 7 14 0	0 4.2 8.3 29.2 58.3 0	4.44
I took this class because (check all that apply)	Personal understanding/interest Teaching certification Understanding of content to aid teaching Continuing education to maintain licensure Progress toward Master's degree Salary progress Other No Answer	19/24 10/24 17/24 14/24 16/24 12/24 1/24 0	79.2 41.7 70.8 58.3 66.7 50.0 4.2 0	

Exit Survey Data
UWRF Summer Physics
PHYS 789 Digital Electronics
Summer 2007

Item	Choices	N	%	Average	σ
Course content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 2 6 7 1	0 5.9 11.8 35.3 41.2 5.9	4.19	0.91
Course format	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 2 3 10 1	0 5.9 11.8 17.6 58.8 5.9	4.38	0.96
Course organization	1: Poor 2: 3: 4: 5: Excellent No Ans	0 1 0 7 8 1	0 5.9 0 41.2 47.1 5.9	4.38	
Instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 7 8 1	0 0 5.9 41.2 47.1 5.9	4.44	

Instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 4 11 1	0 0 5.9 23.5 64.7 5.9	4.63
Course meeting your needs/wants	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 10 4 1	0 0 11.8 58.8 23.5 5.9	4.13
I took this class because (check all that apply)	Personal understanding/interest Teaching certification Understanding of content to aid teaching Continuing education to maintain licensure Progress toward Master's degree Salary progress Other No Answer	10/17 6/17 10/17 4/17 10/17 9/17 0 1	58.8 35.3 58.8 23.5 58.8 52.9 0 5.9	

Exit Survey Data
 UWRF Summer Physics
 PHYS 704: Modern Physics for Secondary School Teachers
 Summer 2006

Item	Choices	N	%	Average	σ
Lecture content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 2 3 12 0	0 0 11.8 17.6 70.6 0	4.57	0.71
Lab content/design	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 2 7 7 0	0 5.9 11.8 41.2 41.2 0	4.21	0.88
Afternoon (alternate lab day) activity content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 0 8 9 0	0 0 0 47.1 52.9 0	4.53	0.51

Share session	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 5 11 0	0 0 5.9 29.4 64.7 0	4.65	0.61
Course format	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 0 3 14 0	0 0 0 17.6 82.4 0	4.82	0.39
Evening problem sessions	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 2 8 6	0 0 5.9 11.8 47.1 35.3	4.64	0.67
Course organization	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 3 13 0	0 0 5.9 17.6 76.5 0	4.71	0.59
Lecture instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 1 1 3 12 0	0 5.9 11.8 17.6 46.2 0	4.53	0.87
Lecture instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 3 14 0	0 0 0 17.6 82.4 0	4.82	0.39
Lab instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 3 14 0	0 0 0 17.6 82.4 0	4.82	0.39

Lab instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 0 17 0	0 0 0 0 100 0	5.00	0
Appropriateness of lab difficulty level	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 5 3 9 0	0 0 29.4 17.6 52.9 0	4.24	0.90
Appropriateness of activity difficulty level	1: Poor 2: 3: 4: 5: Excellent No Ans	0 1 0 5 11 0	0 5.9 0 29.4 64.7 0	4.53	0.80
Course meeting your needs/wants	1: Poor 2: 3: 4: 5: Excellent No Ans	0 1 1 4 11 0	0 5.9 5.9 23.5 64.7 0	4.50	0.87
I took this class because (check all that apply)	Personal understanding/interest Teaching certification Understanding of content to aid teaching Continuing education to maintain licensure Progress toward Master's degree Salary progress Other No Answer	15/17 11/17 13/17 8/17 11/17 11/17 3/17 0	88.2 64.7 76.5 41.2 64.7 64.7 17.6 0		

Exit Survey Data
 UWRF Summer Physics
 PHYS 700 Mechanics for Secondary School Teachers
 Summer 2008

Item	Choices	N	%	Average	σ
Lecture content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 8 12 3	0 0 4.2 33.3 50.0 12.5	4.52	0.60
Lab content/design	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 0 9 12 3	0 0 0 37.5 50.0 12.5	4.57	0.51
Second day lab activities	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 0 10 11 3	0 0 0 41.7 45.8 12.5	4.52	0.51
Share session	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 3 5 13 3	0 0 12.5 20.8 54.2 12.5	4.48	0.75
Course format (lecture, lab)	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 0 3 18 3	0 0 0 12.5 75.0 12.5	4.86	0.36
Evening problem sessions	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 1 0 12 10	0 4.2 4.2 0 50.0 41.7	4.64	0.93

Course organization	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 4 17 3	0 0 0 16.7 70.8 12.5	4.81	0.40
Lecture instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 2 4 15 3	0 0 8.3 16.7 62.5 12.5	4.62	
Lecture instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 4 16 3	0 0 4.2 16.7 66.7 12.5	4.71	
Lab instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 3 18 3	0 0 0 12.5 66.7 12.5	4.86	
Lab instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 2 19 3	0 0 0 8.3 79.2 12.5	4.90	
Course meeting your needs/wants	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 8 13 3	0 0 0 33.3 54.2 12.5	4.62	
Ease of registration	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 4 6 11 3	0 0 16.7 25.0 45.8 12.5	4.33	

Ease of getting housing/food information	1: Poor 2: 3: 4: 5: Excellent No Ans	0 2 4 1 5 12	0 8.3 16.7 4.2 20.8 50.0	3.75
I took this class because (check all that apply)	Personal understanding/interest Teaching certification Understanding of content to aid teaching Continuing education to maintain licensure Progress toward Master's degree Salary progress Other No Answer	18 10 17 8 15 16 0 3	75.0 41.7 70.8 33.3 62.5 66.7 0 12.5	

Exit Survey Data
UWRF Summer Physics
PHYS 720 Optics for Secondary School Teachers
Summer 2008

Item	Choices	N	%	Average	σ
Lecture content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 5 12 0	0 0 5.6 27.8 66.7 0	4.61	0.61
Lab content/design	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 3 14 0	0 0 5.6 16.7 77.8 0	4.72	0.57
Share session	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 4 6 8 0	0 0 22.2 33.3 44.4 0	4.22	
Course format	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 7 10 0	0 0 5.6 38.9 55.6 0	4.50	

Course organization	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 2 15 0	0 0 5.6 11.1 83.3 0	4.78	
Instructor presentation	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 3 15 0	0 0 0 16.7 83.3	4.82	
Instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 0 18 0	0 0 0 0 100 0	5.00	
Course meeting your needs/wants	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 0 3 15 0	0 0 0 16.7 83.3 0	4.83	0.38
I took this class because I wanted	Personal understanding/interest Teaching certification Understanding of content to aid teaching Continuing education to maintain licensure Progress toward Master's degree Salary progress Other	16/18 7/18 17/18 5/18 12/18 12/18 1/18	88.9 38.9 94.4 27.8 66.7 66.7 5.6		

Exit Survey Data
 UWRF Summer Physics
 PHYS 705 Thermodynamics for Secondary School Teachers
 Summer 2008

Item	Choices	N	%	Average
Reading the text	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 3 7 9 2 0	0 14.3 33.3 42.9 9.5 0	3.48
Reading Bare Essentials summary notes on pink paper	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 2 10 9 0	0 0 9.5 47.6 42.9 0	4.33
Simulations	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 2 5 14 0	0 0 9.5 23.8 66.7 0	4.57
Lecture content	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 2 2 9 8 0	0 9.5 9.5 42.9 38.1 0	4.10
Powerpoints	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 5 9 6 0	0 4.8 23.8 42.9 28.6 0	3.95
Matt's conceptual questions	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 1 11 8 0	0 4.8 4.8 52.4 38.1 0	4.24
Conceptual questions from the text	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 5 11 4 0	0 4.8 23.8 52.4 19.0 0	3.86

Problems from the text	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 1 2 10 8 0	0 4.8 9.5 47.6 38.1 0	4.19	0.81
Solving problems with a group	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	2 0 3 3 13 0	9.5 0 14.3 14.3 61.9 0	3.95	1.56
Class discussions	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 3 10 8 0	0 0 14.3 47.6 38.1 0	4.24	0.70
Matt's answers to questions from the class	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 1 11 9 0	0 0 4.8 52.4 42.9 0	4.38	0.59
Lab content/design	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 0 3 8 10 0	0 0 14.3 38.1 47.6 0	4.33	0.73
Quizzes	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	0 2 2 9 8 0	0 9.5 9.5 42.9 38.1 0	4.10	0.94
Course format	1: Not at all useful 2: 3: 4: 5: Extremely useful No Ans	1 0 2 6 13 0	4.8 0 9.5 28.6 61.9 0	4.33	1.02
Course organization	1: Poor 2: 3: 4: 5: Excellent No Ans	1 0 3 9 8 0	4.8 0 14.3 42.9 38.1 0	4.10	1.00
Instructor presentation	1: Poor 2: 3: 4:	0 0 2 10	0 0 9.5 47.6	4.33	0.66

	5: Excellent No Ans	11 0	52.4 0		
Instructor response to student questions/needs	1: Poor 2: 3: 4: 5: Excellent No Ans	0 0 1 9 11 0	0 0 4.8 42.9 52.4 0	4.48	0.60
Course meeting your needs/wants	1: Poor 2: 3: 4: 5: Excellent No Ans	1 0 4 8 8 0	4.8 0 19.0 38.1 38.1 0	4.05	1.02
Ease of registration	1: Poor 2: 3: 4: 5: Excellent No Ans	0 1 2 5 13 0	0 4.8 9.5 23.8 61.9 0	4.43	0.87
Ease of getting housing/food information	1: Poor 2: 3: 4: 5: Excellent No Ans	2 1 4 3 2 9	9.5 4.8 19.0 14.3 9.5 42.9	3.17	1.34
I took this class because I wanted/needed	Personal understanding/interest Teaching certification Understanding of content to aid teaching Continuing education to maintain licensure Progress toward Master's degree Salary progress Other	18/21 8/21 17/21 8/21 13/21 17/21 3/21	85.7 38.1 81.0 38.1 61.9 81.0 14.3		