

USING GARDNER'S MULTIPLE INTELLIGENCE THEORY TO DIFFERENTIATE
HIGH SCHOOL PHYSICS INSTRUCTION

by

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July 2011

TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND	1
CONCEPTUAL FRAMEWORK.....	4
METHODOLOGY	11
DATA AND ANALYSIS.....	20
INTERPRETATION AND CONCLUSION	34
VALUE.....	36
REFERENCES CITED.....	38
APPENDICES	40
<u>APPENDIX A</u> Howard Gardner’s Eight Multiple Intelligences That Are Being Considered	41
<u>APPENDIX B</u> Multiple Intelligence Inventory and Rubric	44
<u>APPENDIX C</u> Nontreatment Sample Lesson Plan.....	48
<u>APPENDIX D</u> Treatment Unit 1 Sample Lesson Plan.....	50
<u>APPENDIX E</u> Treatment Unit 2 Sample Lesson Plan	55
<u>APPENDIX F</u> Daily Journal.....	57
<u>APPENDIX G</u> Pretests and Posttests.....	60
<u>APPENDIX H</u> Interview Questions.....	68
<u>APPENDIX I</u> Student Surveys	73
<u>APPENDIX J</u> Observer Prompts	86
<u>APPENDIX K</u> Personal Survey.....	89
<u>APPENDIX L</u> Timeline.....	91
<u>APPENDIX M</u> Concept Map Rubric.....	94
<u>APPENDIX N</u> Data and Graph Analysis Rubric.....	96

LIST OF TABLES

1. Data Triangulation Matrix	16
2. Average Student Score out of 5 Questions on Pretest and Posttest	21
3. Change in Student's Perceived Understanding from Pre to Postunit Survey	22
4. Perceptions of Student Engagement from Faculty Observer	23
5. Students' Perception of the Units' Difficulty from Pre and Post Unit Surveys.....	26
6. Perceptions of Teacher Attitude from Faculty Observer	31
7. Reflections of Teacher Attitude from Personal Survey	32

LIST OF FIGURES

1. Perception of Students' Understanding of	20
2. Postunit Interview Concept Map Scores.....	21
3. Perception of Students' Engagement from Daily Journaling	22
4. Students' Perceived Engagement from Postunit Surveys.....	24
5. Perception of Students Difficulty from Daily Journaling.....	25
6. Perception of Students' Attitude and Motivation from Daily Journaling.....	27
7. Students' Perception of their Attitude and Motivation from the Postunit Surveys	28

ABSTRACT

The purpose of this project was to examine the effects of differentiated instruction on students' understanding of high school physics based on Gardner's multiple intelligence theory. The original premise was that some students are strong in some intelligences and weak in others. Each student started by learning the content in the areas they were strong in, and then using that knowledge to help them overcome the more challenging concepts. They then worked together with students from all of the intelligence strengths to show a greater understanding of the content and scientific skills. The data was collected using a combination of pre and posttests, surveys, observations, and concept maps as a part of individual student interviews. The results indicate that this approach has its merits but will need refinement to be implemented into the entire curriculum. Differentiation with respect to multiple intelligence theory appears to cause an increase in student understanding, attitude and motivation.

INTRODUCTION AND BACKGROUND

In this project I looked at Howard Gardner's multiple intelligences, which is a theory based on the premise that people have a multitude of different types of intelligences that are independent of one another rather than the traditional single intelligence. As Gardner (2008) states, "intelligence refers to a biopsychological potential of our species to process certain kinds of information in certain kinds of ways". I used these different intelligences as a basis for the differentiation of my instruction of ninth-grade physics instruction. I chose this project topic because, having reflected on the previous two years when this course was taught, I found that students were struggling in the freshman physics course and that differentiated instruction may be a solution to this problem. This is important in that one of the reasons I believe students are doing so poorly in this ninth-grade physics class, is that they are finding it very difficult to take the skills and strengths they do have and apply them to this new content. Previously, the class was taught very much uniformly and few students were really achieving the desired amount of understanding that was expected. Personally, I am of the belief that different people are more intelligent in some areas of life than in others, an idea that corresponds nicely with Howard Gardner's idea of multiple intelligences. Differentiated instruction is an idea that different students should be taught differently and that students will be more successful if the teaching is tailored to the individual. If these two ideas of differentiation and multiple intelligences are put together, then one should be able to differentiate instruction to the strengths of different students' intelligences, such that those students are better able to understand the content and be overall more successful in the class.

The results of this project are significant to different people for different reasons. It helped me understand my students better and gave me better ways to have more content reach more students. My students also benefited greatly as they found that their specific needs were addressed based on what they are strong in. The administration in my district is interested in the results as implementing differentiation has been one of its primary goals the past two years. Other teachers and educators may also find this work significant as they can use this same idea in their classrooms to increase student understanding.

The study was conducted at Antioch Community High School and focused on one section of Physics First, which is a class of ninth-grade students enrolled in physics class specifically designed for freshmen. The class had a total of 26 students participating in the study. The students were mostly white middle class, though there were a few other cultures represented as well, such as African, Latino, and Middle Eastern. There were approximately equal amounts of both genders present as it is a required class for all incoming freshman. These Physics First classes are heavily conceptual but integrate math as it becomes reasonable and useful for students to use as a tool, rather than a burden that needed to be overcome. The concepts that were considered during this study were energy, electricity/circuits, and electrostatics.

This project revolved around one key focus question: What are the effects of using differentiated instruction, which considers multiple intelligences, on students' understanding of ninth-grade physics concepts? I also considered the following five subquestions: what are the effects of differentiated instruction, which considers multiple intelligences, on student engagement in class activities; what are the effects of

differentiated instruction, which considers multiple intelligences, on having each student appropriately challenged to their own academic ability; what are the effects of differentiated instruction, which considers multiple intelligences, on student attitudes and motivation to learn physics; what are the effects of differentiated instruction, which considers multiple intelligences on students' abilities to do data collection, analysis, and interpretation during classroom and laboratory activities; and what are the effects of differentiated instruction, which considers multiple intelligences, on the amount of time I spend planning and grading and my overall attitude toward differentiation practices and teaching as a whole? By the term *differentiation practices*, I am referring to the idea of having to create and teach multiple lessons simultaneously to accommodate the students' various intellectual differences.

The idea is that learning does not only imply understanding the concepts, but also demonstrating skills and becoming motivated to continue learning in the future. It should also be noted that when I refer to levels of cognition, as I did in the above questions, I am referring to the idea that this project was designed to show growth for the individual student, as opposed to reaching some set numerical goal.

Before I address the specific questions of the study, there are a couple of general themes that should be understood as they are present throughout the entirety of the project. The two major themes are the multiple-intelligence theory and differentiation. While officially these are two different standalone theories in education, you will see how the former implies the use of the latter.

This project was supported by a team of professionals made up of science teachers, an English teacher, and two professors of science and science education. They

are: Jewel Reuter, advisor for this project, and professor of science education at Montana State University; Jeff Adams, reader for this project, and professor of physics at Montana State University; Deanna Mazanek, high school science teacher; Rob Schrader, high school Physics First teacher; and Lori Oster, college English teacher.

CONCEPTUAL FRAMEWORK

The idea of this project is to combine two separate, though related, ideas in education; Howard Gardner's Theory of Multiple intelligences, and Carol Ann Tomlinson's educational practice theory of differentiated instruction. I will first show how these two theories are related and then I will look into how these ideas have been used together in the past, which can be useful in finding new ways to combine them in the present. Previous studies have also been done that address one or more of key questions being looked at in this study, though not always combining both differentiation and multiple-intelligence theory. In these studies, differentiation was found to be fairly successful in addressing student understanding, engagement, and allowing students to be appropriately challenged. The students' ability to analyze data was considered and found to not be very successful when taught in a conventional way. The studies that have addressed the idea of increasing student attitudes and motivation and the teacher's attitude towards differentiation have mixed results.

The multiple-intelligence theory was introduced by Howard Gardner (1983). This theory challenged the standard notion of a single intelligence that could be measured, and rather proposed that there are different types of intelligences and that different people

will show greater strengths in some as opposed to others. To be clear that these are each different intelligences and not simply different aspects of one, Gardner uses eight criteria to ensure that these are independent intelligences, and that each is separate and distinct from the others. Gardner first proposed seven different intelligences that people have in varying degrees. Twenty-three years later, Gardner (2006) added an eighth intelligence to his list. There was much discussion about a proposed ninth intelligence, but with the lack of certain evidence, Gardner remained skeptical to add it to the list. The following lists those eight intelligences as proposed by Howard Gardner: Verbal-Linguistic, Musical, Logical-Mathematical, Visual-Spatial, Bodily-Kinesthetic, Interpersonal, Intrapersonal, and Naturalist. The proposed ninth is Existential Intelligence. Besides it not being officially agreed on as an intelligence, it is also quite difficult to use as a basis for learning physics concepts in a high school classroom, so for both of those reasons it will not be addressed further in this project (Gardner, 1983, 2006). To better understand why some of the practices are being used, it is important to have at least a brief understanding of each of the eight intelligences; please see Appendix A.

These different intelligences are the basis for the differentiation of instruction that will be done throughout the study. Of course this suggests the question, what exactly is differentiation and how is it used in conjunction with multiple intelligences? To begin to answer that question one must look at the work of Tomlinson (1999); she is one of the largest proponents of differentiation and makes great arguments for it. Differentiation opposes the idea of a uniform curriculum; rather it focuses on the idea that every student is different and has different strengths, therefore, every student should be taught differently. There are a number of ways in which to differentiate. Tomlinson lists those

as differentiating by content, process, product, or learning environment. Differentiation by content allows the teacher to change what the individual student actually learns. This means that not all students will necessarily be learning all of the same things at the same time. Differentiation by process is when the activities that the students do to learn are different, but the content is the same. An example might be having one group of students read a book on the related content, whereas, others might watch a video on it, or go see a play about it. Differentiation by product allows the students to demonstrate a learned concept in different ways. While some students may write a report on a topic, others might put on a skit. Lastly, differentiation by environment would be changing the classroom conditions to best suit each student. Some students might prefer to work in small quiet rooms with minimal distraction, while others may prefer a looser atmosphere where they can listen to music or chat quietly. It should be noted that differentiating the environment is something most teachers are not able to do on their own, as they usually have but one classroom; however, administrations often make use of this concept with regard to which types of classes have a smaller class size and such (Tomlinson, 1999).

One of the most common ways that differentiation by process and product is done is by using different learning styles, i.e. visual, auditory, or kinesthetic. The idea being that students with a visual learning style preference learn concepts better when presented visually, i.e. text on screen, graphs, and pictures. The same idea is true for auditory students having a preference to verbal instruction or peer communication, and kinesthetic students have a preference for physically manipulating objects and moving around to act things out (Flemming, 2001). One can understand how an assignment can be focused more towards one style than another to differentiate for different students. I propose that

a similar concept be used, but rather than differentiating to different learning styles, differentiating to the different intelligences that students possess.

With the key idea of the study looking at the effects of using multiple intelligence based differentiated instruction, one must first consider sources where similar work has been done before. A particular study by Noble (2004), focuses heavily on the combined use of multiple-intelligence theory and the use of Bloom's Revised Taxonomy. Bloom's Taxonomy is a way to classify learning objectives based on different levels of cognitive process, starting at basic knowledge and fact recall, and working up to analysis of those concepts, synthesizing them with other concepts, and evaluating those concepts as to their validity. Bloom's Revised Taxonomy is reorganized with updated vocabulary to be more applicable in the modern day (Huitt, 2009). Nobel's 2004 study involved 16 teachers from two schools, teaching Grades K-6, and all implementing the combined use of multiple-intelligence theory and Bloom's Revised Taxonomy to increase their students' understanding of the content. She states that, "The teachers reported consistently that the typologies of MI [multiple-intelligence] theory and RBT [Bloom's Revised Taxonomy] helped them in different ways to cater to the individual learning capabilities of the students in their classes and thereby facilitated student success" (Noble, 2004, p. 196). While this study was specifically designed for bilingual students, Noble specifically addresses their understanding with regard to the use of multiple intelligence theory when she states, "these teachers perceived that the MI framework was providing more options for children who were not academically or linguistically strong in English to demonstrate their knowledge and understanding in other ways" (Noble, 2004, p. 197).

With respect to the subquestions surrounding this study, one must look at how other studies may have addressed each of these questions in the past; the first subquestion concerns the effects of differentiated instruction on student engagement. A study on improving math skills through differentiation that spanned most of the grade levels in both elementary and secondary education by Ellis, Ellis, Huemann, and Stolarik (2007), found that when students were given a choice of assignments and when they were allowed to use different intelligences, students were more engaged in the activities. This study separated the use of differentiation in which the three-tiered approach was used from designing lessons where the students could use one or more of Gardner's multiple intelligences (Ellis et al., 2007).

The second subquestion of the study concerns the effects of differentiated instruction, which considers multiple intelligences, on having each student appropriately challenged to their own academic ability. In a study by Fenner, Mansour, and Sydor, (2010), the idea of having students progress at their own academic ability was addressed. The study examined sixth, seventh, and eighth-grade students in a family and consumer science classroom. While the study was heavily focused on student motivation, time was given to the idea of making sure each student was correctly challenged. In the conclusion the author stated, "Differentiated assignments allowed students to grow academically according to their ability level" (Fenner et al., p. 84). This implies that through differentiation students were in fact challenged appropriately for their level.

The third subquestion concerns the effects of differentiated instruction, which considers multiple intelligences, on students' attitudes and motivations to learn physics. The Fenner study states that "using differentiated strategies allowed students to become

motivated according to their ability” and “...the majority of students showed an increase in motivation. This increase was a result of using differentiated methods of instruction in a classroom setting.” (Fenner et al., 2010, p. i). In a study, by Danzi, Reul, and Smith (2008), however, where fifth and eighth-grade students were tested to see if using differentiation could decrease the students’ boredom and increase their motivation, the researchers concluded that there was no significant increase in motivation, and in reviewing the data they presented there are even times when pretest and posttest data suggested that the students exhibited a higher lack of motivation after the treatment than they had before.

The abilities of students to collect, analyze, and interpret data was considered by Volkwyn, Allie, and Buffler (2008) with a study of college freshman physics students. The laboratory skills of the students were tested using pre and postunit assessment analysis to see if the conventional way of teaching laboratory skills was in fact beneficial. “The findings show that the laboratory course improved the performance of the majority of students insofar as the more mechanical aspects of data collection and data processing were concerned. However, only about 20% of the cohort of physics majors exhibited a deeper understanding of measurement uncertainty required for data comparison” (Volkwyn et al., 2008, p. 1). While the study explored neither differentiation nor multiple intelligence theory, it does show that conventional methods of teaching laboratory skills did not yield the understanding expected.

The final subquestion concerns the amount of time I spend planning and grading, which will affect my overall attitude toward differentiation practices and teaching as a whole. In a study, by Latz, Neumeister, Adams, and Pierce (2009), to see if mentoring

increases teacher motivation to use differentiation practices, only three of the 20 teachers in the study claimed to have had a negative experience (Latz et al., 2009), thus, implying that 17 were very content using differentiation practices in their classroom. In the Ellis et al. (2007) study, the teachers claimed that designing differentiated lessons took up much more of their time than they had thought it would. They also stated, however, that the payout was worth it (Ellis et al., 2007).

As can be seen from the literature, the idea of looking at students having multiple intelligences, leads to the idea of using differentiation as a technique to teach to those intelligences. So, how can this be integrated into the physics classroom? One particular article by Guignon (2010), states that two of the best ways to implement multiple intelligences into the classroom is to design lessons that allow the students to use more than one intelligence and to create assessments in which students can show their mastery of the content in different ways such that it would be most applicable to their intelligence (Guignon, 2010).

From the literature it is clear that multiple-intelligence theory suggests that different people have different strengths with respect to eight different intelligences. Differentiation is the theory that all students are different and, therefore, should be taught differently. From the sources concerning the questions surrounding this study specifically, it can be seen that there has been some success increasing student understanding using multiple intelligence theory before. Students appear to be more engaged when they can use different intelligences. Differentiation allowed students to be more appropriately challenged to their ability level and generally increased students' motivations and attitudes to learn. Conventional methods of teaching laboratory skills

may be not be very effective. While differentiation does appear to require an increase in the amount of work from conventional teaching, the success may be worth the additional effort.

METHODOLOGY

Project Treatment

This project was done over three different units in the curriculum. The first unit was a nontreatment unit, whereas, the second and third units were both treatment units. The reason for this is so a comparison could be made between when differentiation practices that consider multiple intelligences were not used as a teaching tool as opposed to when they were implemented. The nontreatment unit covered the concept of energy. During this unit, no special attention was given towards the students' intelligence strengths and was not differentiated. The unit covered the major concepts of energy such as conservation, kinetic energy, and potential energy. These concepts were applied to situations in which an object's energy is converted between the two different forms, and was explored experimentally, conceptually, graphically, and mathematically. The two treatment units were Electricity/Circuits and Electrostatics. Throughout both of these units, students' learning was based on their different multiple intelligence strengths and, therefore, their instruction was differentiated as different students were not all doing the same assignments at the same time. Throughout the electricity/circuits unit, the students learned Ohm's Law, the concepts of voltage, current and resistance, circuit diagrams, as well as series and parallel circuits. In the electrostatics unit, the students learned about

charge, Coulomb's Law, conductors, insulators, and methods of charging. Once again, all of this was done experimentally, conceptually, graphically, and mathematically.

As stated, the nontreatment unit was on energy. In this unit the students were all working on the same things at the time, as one would find in a typical classroom. The students started by taking a qualitative look at two different forms of mechanical energy, kinetic and potential. The students also went through the law of conservation of energy and applied it to these two different types. They performed a quantitative lab, where they used the potential energy equation to calculate the amount of energy a marble had based on its height, and then after allowing it to roll down a ramp, measured its velocity and compared the two energy values to see if energy was conserved. Upon completing that, they then solved problems using the equations they learned, and the idea of applying it to conservation situations. The important point is that all of the students were doing the same assignments at the same time.

Prior to the treatment units, the students were assessed on their multiple intelligence profiles, using the multiple intelligence inventory and scoring rubric in Appendix B, to see which intelligences seemed to be the strongest. The intelligence that was strongest, determined how I differentiated their instruction. Students with a strong linguistic intelligence began the electricity unit by looking at the different concepts and writing analogies and descriptions for the concepts of voltage, current, resistance, series circuits, and parallel circuits. Only then did they perform the lab based and graphing activities, which they could then apply to the mathematic aspects and use equations to solve problems. Those with a strong logical and mathematical intelligence started out by using the equations to solve problems, and explain the concepts using mathematical

notation of variables being directly or inversely related, etc. They then used that knowledge to begin to describe those same concepts in words and create formal written descriptions of the concepts at hand. They then used both of those concepts to create and analyze graphs. A similar approach was used for students with a visual/spatial primary intelligence as well, where the initial focus was for them to use their strength intelligence where they created and analyzed graphs as well as experimented with computer software generated circuits so they could visualize what was happening. Upon completion of their strongest intelligence activity, they began to address their weaker intelligences by creating written descriptions, and solving for mathematical relationships. The idea is that while all of the students did eventually complete all of the same types of assignments, it was the order in which they did them that created a difference in how well they succeed at them.

In a sample nontreatment lesson, see Appendix C, the students performed an activity where they used linguistic, mathematical, and spatial intelligence to explain a new concept, in this case it was the conservation of energy law. This is representative of how a typical science class lesson is run, in that a single concept is presented to the students in a number of different ways. From my experience, however, when the information is presented in this format, most students only comprehend the concept at one level. In a sample lesson of the first treatment unit on Ohm's Law, see Appendix D, the students were split into groups based on their intelligence strengths. This lesson is made up three smaller lessons for each of the three different intelligences, and each student did complete all three, but in the order that was most suited toward them, and only working with one intelligence at a time. This focuses on the idea that the students

learned the concept in only the best format for them first, instead of three formats at the same time, two of which were not their strongest. Only after gaining understanding of the concept in their strength did they take what they had learned and use that to help them learn the different aspects of the content with which they were less comfortable with. In Appendix E, a sample of another treatment lesson, this one on Coulomb's Law, can be seen. The idea for this lesson was that students would develop a comfort for using all of their intelligences together to solve complex problems only after they learned the required content each intelligence individually first.

In short, there were three basic phases of the treatment unit followed by a test. Phase 1 was to become familiar with the content in the students' own strength intelligence. This included solving mathematical physics problems, describing the concept or the relationship between two variables in words, or drawing graphs and diagrams to represent that concept or relationship. It depended on the individual student's primary intelligence. Phase 2 was using that familiarity with their primary intelligence to learn the concepts that required the other intelligences. To an outsider it would have appeared identical to phase 1 as the students were engaged in the same activities, the only difference being that the activities they worked on were suited towards their secondary and tertiary intelligences. Phase 3 took all of the content from all of the intelligences and used them together in a single project. In this case each group had members with different primary intelligences so that they could work together to show the content in all three ways.

The idea behind this treatment of differentiating to the different multiple intelligences is that students started by understanding each concept with their strength. In physics, however, a student must be able to explain concepts in a number of different ways, so once they have a fundamental concept in their strength intelligence, they can use that as a guide as they begin to work through the concept using some of their weaker intelligences. Ideally, not only will the students come to understand the concept as a whole better, but they will also strengthen their weaker intelligences and become more comfortable with them in the future.

Data Collection Instruments

The 26 students that participated in the study were enrolled in a Physics First class, which is a ninth-grade physics course. About 90% of the students were taking Algebra 1 concurrently with Physics First, and had only begun to manipulate equations and study the slopes of graphs. The other 10% were either taking a slower version of Algebra 1 that spans it over two years, or an honors version of Algebra 1, and had some experience with equations and graphs in the past, though were often weak at interpreting them and explaining the graph's meaning in words. The students were an even mix with respect to gender, and there are a number of different ethnicities, though most of the students came from middle class white families. It should be noted that the research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

Table 1 is a triangulation matrix of the focus question and subquestions.

Table 1
Data Triangulation Matrix

Research Questions	Data Source			
	1	2	3	4
Focus Question: students' understanding of ninth grade physics concepts	Daily journaling per journal prompts	Quantitative pretest and posttest data for each unit per pretests and posttests	Interviews with concept mapping per postunit interview forms and concept map rubric	Pre/postunit student surveys
Subquestion 1: student engagement	Daily journaling per journal prompts	Classroom observations by colleague per observer form	Postunit nontreatment and postunit treatment 2 interviews	Postunit student surveys
Subquestion 2: each student appropriately challenged to their own academic ability	Daily journaling per journal prompts	Interviews per postunit nontreatment and postunit treatment 2 interview forms	Pre/postunit student surveys	
Subquestion 3: student attitudes and motivation	Daily journaling per journal prompts	Postunit nontreatment and postunit treatment 2 interviews	Postunit student surveys	
Subquestion 4: students' abilities at collection, analysis, and interpretation of data	Daily journaling per journal prompts	Analysis of student graphs per data and graph rubric	Interviews with graphing per postunit interview forms	
Subquestion 5: my overall attitude toward differentiation practices	Daily journaling per journal prompts	Classroom observations by colleague per observer form	End of unit personal survey per personal survey	

For the focus question, which addresses students' understanding of the concepts, I used daily journaling, see Appendix F, to track my interpretation of how well the students understood the content. This was done by me after each lesson each day. These data were used to compare student understanding of content. It should be noted that for this and every other data instrument used, the treatment data was compared to the nontreatment data to look for growth, differences, and anomalies. Pretests and posttests, see Appendix G, were given to the students before and after each of the three units and scored out of five points. Before and after each unit, six students were chosen and then interviewed using the guides in Appendix H, two each from a different primary intelligence. The students were asked to explain the concepts of that unit using a concept map to gauge how well the students understood the conceptual material. This was scored using the concept map rubric in Appendix M. All students were also given a survey; see Appendix I, before and after each of the units in which they would rank their own perception of how well they thought they understood the material.

Subquestion 1 uses the data to look for an increase in student engagement. I used daily journaling, as can be seen in Appendix F, to track how well the students were engaged in each lesson. This was done by me after each lesson each day. During each unit, I had a colleague of mine observe one of my lessons, and rate how engaged he thought the students were in the material, see Appendix J, which could then be used for comparison. After the nontreatment unit and the second treatment unit, one of the questions in the interview, see Appendix H, allowed the students to reflect on how engaging they felt that unit to be for comparison. As per the surveys in Appendix I, all of

the students were asked at the end of each unit to rate how engaged they felt that unit to be and why, so the results could be compared.

Subquestion 2 is about the students showing that they are appropriately challenged to their own academic ability. I used daily journaling, as can be seen in Appendix F, to track how appropriately challenged the students were to their own academic ability based on that day's lesson. This was done by me after each lesson each day and then later compared. After the nontreatment unit and the second treatment unit, one of the questions in the interview, see Appendix H, allowed the students to reflect on how appropriately challenging they felt that unit to be for comparison. All of the students were also given a survey, see Appendix I, before and after each of the units in which they would rank how appropriately challenging they perceived that unit to be, so that could be later compared.

Subquestion 3 looks at how students' attitudes towards differentiation, physics, and science in general may be affected by these differentiation practices. I used daily journaling, as can be seen in Appendix F, to track my perception of the students' attitudes and motivations in each lesson. This was done by me after each lesson each day. After the nontreatment unit and the second treatment unit, one of the questions in the interview, see Appendix H, allowed the students to reflect on how enjoyable they found that unit to be for comparison. As per the surveys in Appendix I, all of the students were asked at the end of each unit to rate their attitude for that unit and to explain why.

Subquestion 4 looks specifically at how the students' data analysis and graphing skills are progressing. I used daily journaling, as can be seen in Appendix F, to note any specific difficulties I noticed the students were having in the data collection and analysis

process. This was done by me after each lesson each day. Throughout each of the units, students were required to collect and analyze raw data, as well as graph that data and be able to explain how the data is represented by the graph. During each unit, the students work was analyzed, using the rubric in Appendix N, for mistakes and misconceptions to see if there was a discrepancy in the students' abilities to collect and analyze data in the nontreatment unit as opposed to the treatment units. In each of the postunit interviews, see Appendix H, the students were given a set of raw data and asked to explain how they might analyze that data. They were also expected to graph that data and explain how the graph gave information about the data.

Finally, subquestion 5 refers specifically to how well I enjoyed differentiation, and how effective it was for me to implement as a teacher. I used daily journaling, as can be seen in Appendix F, in which I would discuss how I felt each lesson to go, how much time and effort it took to plan it, and whether the amount of effort that went into the planning appeared to be worth the outcome. This was done by me after each lesson each day. The data collected was useful because I was able to compare my overall attitudes of teaching in the traditional style to using this specific form of differentiation and see if there were any differences. A colleague of mine observed one of my lessons each unit, and rated my overall attitude with respect to teaching and planning my lesson, see Appendix J. Appendix K shows the personal survey that I completed at the end of each unit so I could get a gage of what my own personal attitudes were and compare them.

The pretests and posttest were quantitative data; therefore, the average scores on those exams were examined and compared to each other directly. All Likert scale based questions on the surveys, journals, and observations are also quantitative, so the

numerical scores were compared to each other, though this was done by using a 5-point scale to rate a qualitative concept quantitatively. The interviews, other parts of the surveys, journaling, and observation are all qualitative and were looked at for trends patterns and discrepancies from each other. A timeline of this entire process can be found in Appendix L.

DATA AND ANALYSIS

The main focus of this project was to investigate how much of an effect differentiated instruction had on the students' understanding of the content. Figure 1 shows the average score, based on a 5-point Likert scale, of how well it appeared that the students' understood the content, as noted in the students' daily journaling.

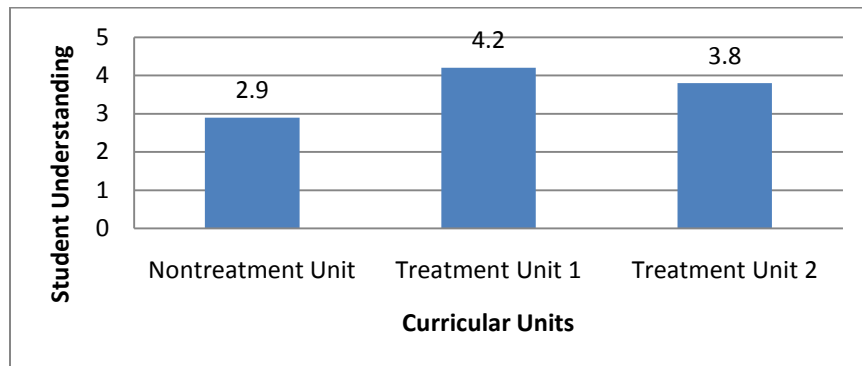


Figure 1. Perception of students' understanding of content ($N=43$).

Note. Likert scale 5=very high understanding, 4=higher understanding, 3=average understanding, 2=some understanding, 1=no understanding.

The figure shows that while the students appeared to struggle with the content in the nontreatment unit, they appeared to understand much more of the material during the units that contained the differentiation. This is also consistent with the journaling notes taken during first treatment unit, which state, "The students have grasped Ohm's law very

well as they are performing calculations as conceptually explaining the relationship between voltage, current, and resistance.”

The pretest and posttest data in Table 2 show that the students had an overall better understanding of the content prior to the nontreatment unit as opposed the differentiated treatment units, and yet during the posttest, the students had an overall better understanding in both treatment units as compared to the nontreatment unit.

Table 2

Average Student Score out of 5 Questions on Pretest and Posttest (N=26)

Description of data	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Pretest	1.38	0.83	0.98
Posttest	2.08	2.95	2.92
Percent Change	50%	258%	198%

Students had 258% change in Treatment unit 1 and 198% change in Treatment unit 2 compared to a 50% change during the nontreatment unit.

Using the concept maps created by the students, Figure 2 shows the average percentage scored on those concept maps, using the rubric in Appendix M, based on a standard score as determined by the teacher creating the same concept map and using the same rubric. The students increased their understanding in each successive unit.

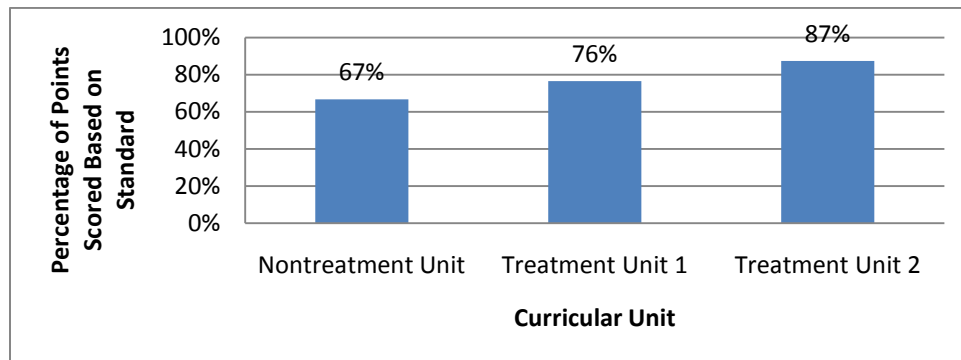


Figure 2. Postunit interview concept map scores (N=6).

Using pre and postunit surveys, where the students used a 5-point Likert scale to rank their current understanding of the content in each unit, the average percent change of that understanding is shown for each unit in Table 3.

Table 3

Change in Student's Perceived Understanding from Pre to Postunit Survey (N=26)

Description of data	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Pretest	2.36	2.43	2.08
Posttest	3.70	4.05	3.70
Percent Change	57%	66%	78%

Note. Likert scale 5= very positive attitude, 1= very negative attitude.

Notice that in every one of these sets of data, there is greater increase in perceived understanding during each of the differentiated treatment units than there was in the traditional nontreatment unit.

While the main focus of the investigation was student understanding, other factors were also considered in attempting to determine the usefulness of multiple intelligence-based differentiation; such as student engagement. Figure 3 shows the average Likert scale score for student engagement as recorded by journaling throughout each unit. From this graph it appears that students were least engaged in the nontreatment unit, became very engaged by the first treatment unit, and then a little less engaged in the second treatment unit.

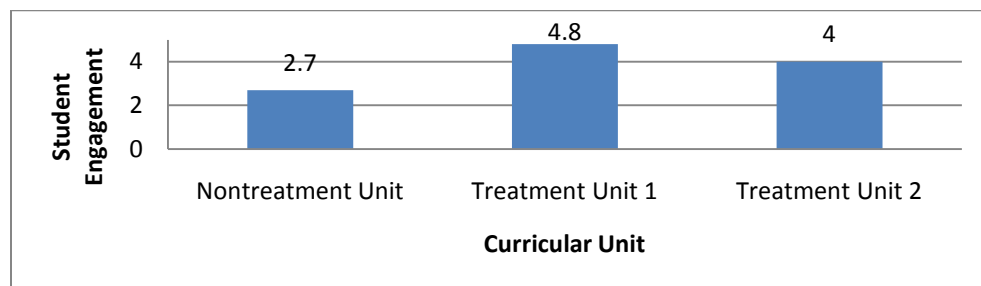


Figure 3. Perception of students' engagement from daily journaling (N=43).

Note. Likert scale 5=very high understanding, 4=higher understanding, 3=average understanding, 2=some understanding, 1=no understanding.

This is quite consistent with the notes made by a colleague who observed one day in each of the three units, and can be seen in Table 4 where the same 5-point Likert scale was used.

Table 4

<i>Perceptions of Student Engagement from Faculty Observer (N=3)</i>			
Description of data	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Student Engagement	2	4	3

This same trend shows engagement was low in the nontreatment unit, high in the first treatment unit, and in between those two during the second treatment unit.

Additionally, the observer's notes also stated, "students were giving up easily, and preferred to talk amongst themselves" during the nontreatment unit, and, "the students worked very hard with each other on the Ohm's Law worksheets" during the first treatment unit. He also stated during the second treatment unit that, "the students appeared to working well at first, but after a short while began to get bored and started to rush through." These notes are very consistent with the Likert scale scores.

In the interview following both nontreatment unit and the second treatment unit, one of the questions asked was specifically geared towards getting insight on the students' engagement. Of the six students interviewed after the nontreatment unit, three stated they were engaged, two said they were "kind of" engaged, and one student said that he found the unit engaging. The general reasoning behind these responses was that the material was difficult, and to quote one of the students, "besides the lab, the stuff we did was boring." This differs greatly with their responses after the treatment units in which five of the students claimed that they were engaged by the treatment units, one specifically stating, "I liked having people to work with in the flavor groups [a term we used to mean groups separated by intelligence strength] because different people would

figure out different parts and then we could get the right answers.” These responses indicate that the students were much more willing to work when they were in the differentiated groups than when they had to take notes and work in a more traditional classroom.

Figure 4 shows the students average responses to when they were asked to rank their engagement after each unit using the same 5-point Likert scale.

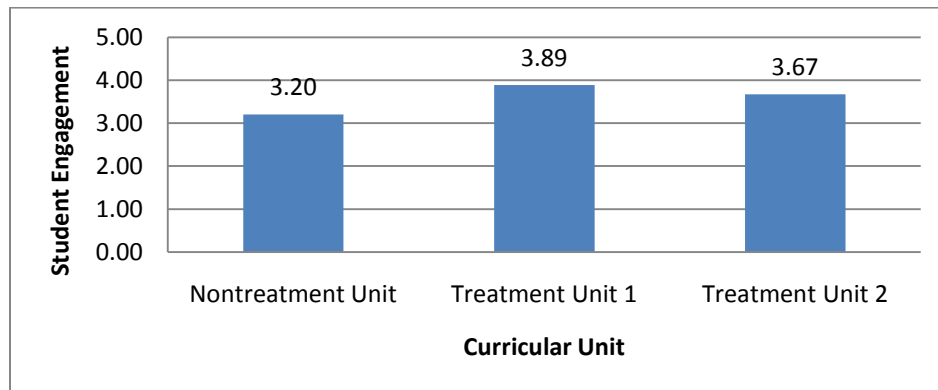


Figure 4. Students’ perceived engagement from postunit surveys ($N=26$).
Note. Likert scale 5= very positive attitude, 1= very negative attitude.

While the amount of variation is much less in this set of data than from the previous set using the daily journaling, the trend is still the same, with the nontreatment unit having the least amount of student engagement, the first treatment having the most, and the second treatment having an amount in between. It should be noted that because all three of these values are very close to each other, this could indicate that most of the students perceived their own engagement in each unit as being fairly constant; though the remainder of the data sets seem to indicate a stronger relationship.

Another factor that was considered in this investigation was ensuring that the students were appropriately challenged for their grade level. Figure 5 shows how challenged it appeared the students were with each of the three units.

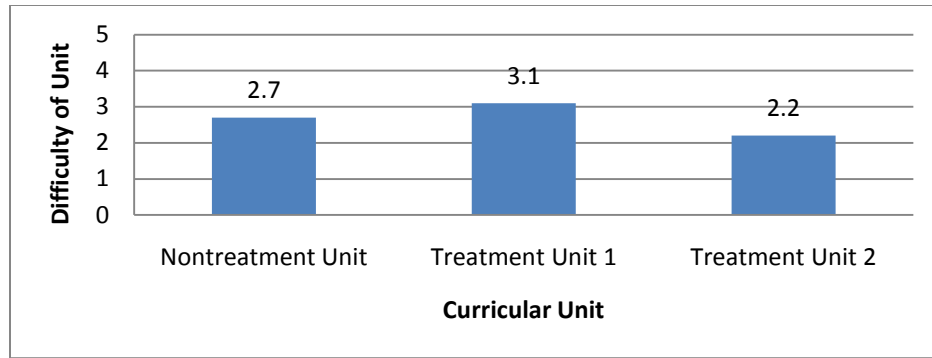


Figure 5. Perception of students difficulty from daily journaling ($N=43$).
Note. Likert scale 5=very easy, 4=easy, 3=at grade level, 2=challenging, 1=very challenging.

In the nontreatment and treatment 1 units, the students seemed close to be appropriately challenged, with the nontreatment being just a little more difficult. The second treatment unit, however, proved to be very difficult as the students struggled with one of the major pieces of content. The inconsistencies of the treatment data with respect to the nontreatment data indicate that how challenged the students are may not be influenced greatly by the method of instruction, but more due to what the content is that is being presented. This is supported by a quote taken from one of the daily journal logs during the second treatment unit. “The students are greatly struggling with inverse square law in all three intelligence types. This may just be too difficult for students who are concurrently taking Algebra 1.”

Some of the students were interviewed and asked about how challenging they perceived these units to be. The first was in the interview just after the nontreatment unit, while second was after the completion the second treatment unit. During the nontreatment postunit interviews, all six of the students interviewed stated that the material was challenging but at what they considered to be at grade level. To quote one, “It was kind of hard, but I think I was starting to get it by the test.” In the second

interview, the students were not only asked how challenging the units were, but whether or not they thought that the format made a difference. One of the students thought that the content was too easy, and maybe even a little below grade level, though the other five stated that it was appropriately challenging. When asked whether the way the material was presented made a difference, one student specifically stated, “The group stuff helped make it easier.” This indicates that the student’s perceptions of the material may have been made less challenging by the format, though this is slightly inconsistent with the findings from the journaling.

Prior to and just after each unit, the students ranked either how challenging they thought the unit was going to be, or how challenging the unit actually was, as seen in Table 5. This was done using the same 5-point Likert scale as used during the daily journaling.

Table 5

Students' Perception of the Unit's Difficulty from Pre and Postunit Surveys(N=26)

Description of data	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Preunit Survey	2.9	3.2	3.2
Postunit Survey	3.3	3.4	3.5
Difference	0.4	0.3	0.3

Note. Likert scale 5= very positive attitude, 1= very negative attitude.

While all of the average data was near a Likert scale score of 3, indicating that the units were thought to be appropriately challenging, it should be noted that the difference in scores from before to after is all about the same as well. This indicates that differentiation may not have much influence on how challenging the unit is perceived to be by the students. While how challenging the students perceived the second treatment

unit to be, in both the interviews and the surveys, was inconsistent with the teacher's findings in the journal, this difference in perception could indicate that the differentiation did not actually change how challenging it was, but how challenging the students perceived it to be. However, due to the fact that is a single piece of data, as treatment 1 data does not specifically support this, there is not enough information to definitively conclude this.

This investigation also considered the students' attitude and motivation in each unit (Figure 6).

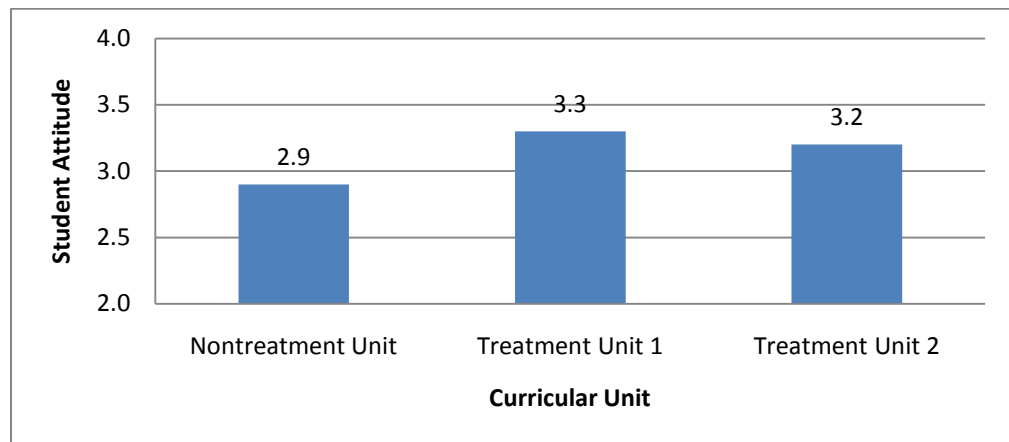


Figure 6. Perception of students' attitude and motivation from daily journaling ($N=43$). *Note.* Likert scale 5= very positive attitude, 4= positive attitude, 3= indifferent attitude, 2= negative attitude, 1= very negative attitude.

The data show that students' attitude and motivation was more positive during the treatment units than it was during the nontreatment unit. This is seen further in that during the nontreatment unit the journaling noted that, "the students had a generally poor disposition today when we went through the creation of energy pie charts." Whereas, during treatment unit 2, it was observed in the journaling that, "students were very excited today as they discussed in their project groups real life example of how insulators and conductors can be used."

In the nontreatment postunit interviews, the students, fairly unanimously, stated that they generally enjoyed coming to class because they liked the teacher, the students, and the atmosphere. A couple of students did not particularly like the subject, and most stated that they were very turned off by the class work, which consisted of bookwork, and note taking, but really enjoyed labs and group activities but said that there weren't enough., to quote one, “we take [lecture] notes too often, we should do more labs.” In the interviews after the treatment units, the students had generally the same opinion on what parts of class they enjoyed, though stated that were happier because, “There were a lot of group activities so that was good.”

When students took their postunit surveys, they used the same 5-point Likert scale as was used in the daily journaling, with the results being shown in Figure 7.

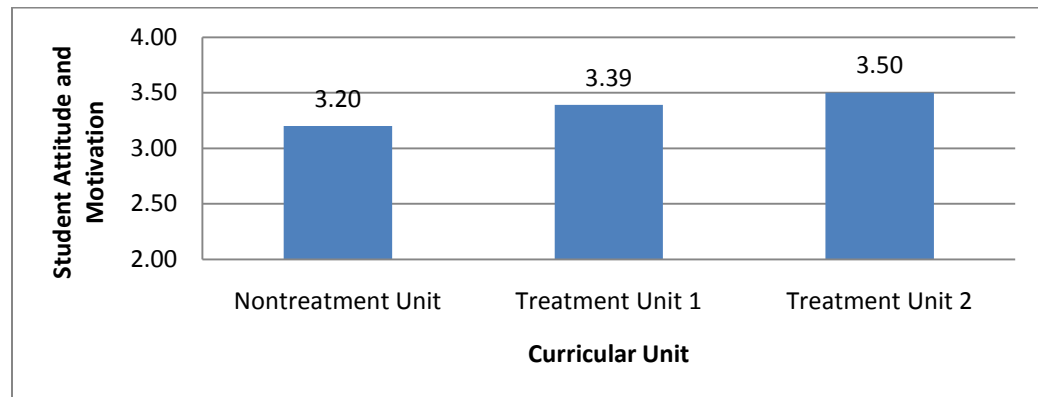


Figure 7. Students’ perception of their attitude and motivation from the postunit surveys ($N=26$).

Note. Likert scale 5= very positive attitude, 1= very negative attitude.

While all very close to each other, the data does indicate a slightly increased attitude and motivation during the treatment units as opposed the nontreatment unit. In addition to this, the students were asked in both treatment postunit surveys if they preferred the differentiated instruction as opposed to a more a traditional type. While there were differing opinions, most students stated that they enjoyed the differentiated

instruction more because, “working in groups is more fun.” Of the few students who preferred the traditional instruction, most of those students were not very social and stated that, “I like to work by myself better.” These data appear to be consistent with that of the interviews and the daily journaling.

It was also important to consider whether or not this form of differentiation has any effect on students’ data collection and analysis skills. In the daily journaling, it was noted that during labs throughout the nontreatment unit, the students, while understanding basic data collection procedure, were very inaccurate and made many errors. “The students took sloppy data and often times were unsure of what to do with the measurements they had taken.” Throughout the labs in the first treatment unit, it was noticed that students’ data collection skills had increased and they were able to take much more meaningful and accurate data. “The students did great in lab today and had no problems switching back and forth from voltage to current on the multi-meters.” It should be noted that labs in treatment unit 1 had less complex tasks that needed to be performed than in the energy labs in the nontreatment unit. Treatment unit 2 had no labs where they have very much quantitative data taken, but rather the students performed laboratory activities qualitatively observing phenomena. “The students did well describing the three different methods of charging from the different activities today.” This indicates that students took more accurate data during the treatment units than they did during the nontreatment unit.

Using the rubric located in Appendix N, the graphs created by the students for each lab were qualitatively assessed. In the nontreatment unit, the students had much difficulty scaling axes, most students could plot the data onto the graph fairly well, but

very few of them could state anything meaningful about the data from the graph. In the first treatment unit, the students worked together to create their graphs that were both scaled and plotted correctly, and some were starting to make correct conclusions about what the data meant by looking at things like slope and direction of data. In the second treatment unit, due to the lack of quantitative data taken, the graphing skills could not be assessed. It does appear that the students were able to use their differentiated groups to their advantage during labs and create more accurate graphs as well as find more accurate meaning from them.

In each postunit interview, each student was asked to create a graph from a set of data and explain what that data meant by creating and analyzing a graph. In the nontreatment unit, all of the students were able to state that the direct relationship, “as velocity goes up so does the kinetic energy.” Four of the six correctly graphed the data with the correct curve shape, two created linear graphs instead. Of those four students, only two were able to state that the shape indicated a nonconstant relationship. In the treatment unit, all of the students correctly created the linear graph, five were able to state that this indicated a constant relationship, and two even went on to correctly explain that that slope indicated the variable on the Y-axis (voltage) was related to the variable on the X-axis (current). In the second treatment unit, all six students correctly graphed the data with the correct curve shape and four indicated that it had a nonconstant relationship. “It’s not constant because the slope is changing.” These interviews show that the students were able to create graphs and explain them better during the end of the treatment units than they were at the end of the nontreatment units. This is consistent with the data from the qualitative graph rubric and daily journaling.

The last factor considered when trying to implement this form of differentiation was how it would affect my overall attitude toward differentiation considering possible increased amounts of time planning and grading. These results can be seen in Table 6.

Table 6

Perceptions of Teacher Attitude from Faculty Observer (N=3)

Description of data	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Teacher Attitude	3	5	4

Note. Likert scale 5= very positive attitude, 4= positive attitude, 3= indifferent attitude, 2= negative attitude, 1= very negative attitude.

My colleague observed my attitude in the nontreatment unit as, “started very positive, but became more anxious and frustrated at the students throughout the lesson”. In the first treatment unit observation he stated. “very positive” and “complimented the students often on their work.” In the second treatment unit he stated, “teacher and student interaction was mostly positive throughout the lesson.” From both Table 5 and his descriptions, my attitude was more positive in the treatment units than it was during the nontreatment unit.

In the daily journal prompts, I found that during the nontreatment unit I was a little frustrated on some days as a result of the students’ behavior, but the amount of time I spent planning was fairly consistent with what it had been in the past. There were positives and negatives to my attitude during treatment unit 1. I was genuinely elated at how the students were responding to the differentiation, which was mostly seen in the classroom. Outside of class, however, I was becoming very frustrated with a fairly increased amount of plan time, with multiple- group activities to set up, projects to create, and a slight increase in the amount of grading. In the treatment 2 unit, I found that the initial elation based on the students’ response had worn off a little bit, but I was still fairly

excited by how the differentiation was going in the classroom. I also found that as I created more differentiated lessons it became easier and started to take less time. “I’m finding that planning is taking less time that it had before because I can use the previous lessons and worksheets as templates for the new ones. I believe that as with anything new there was probably a period of acclimation in which I needed to become more efficient and more proficient with the entire differentiation process.” The previous quote was taken from the very last journal entry of the second treatment unit. These entries indicate an increase in teacher attitude in the classroom during the treatment units. With regard to time involved in planning and grading, there was an initial decrease in attitude in treatment unit 1, but then increased again in treatment unit 2 as familiarity was gained.

At the end of each unit, I took a personal survey to rank my overall attitude toward differentiation with respect to teaching it in the classroom and also amount of time planning and grading. These were ranked based on the same 5-point Likert scale as the colleague observation and can be seen in Table 7.

Table 7

Reflections of Teacher Attitude from Personal Survey (N=3)

Description of data	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Attitude with respect to planning	3	2	3
Attitude in classroom	3	5	4

Note. Likert scale 5= very positive attitude, 1= very negative attitude.

My attitude with respect to amount of time was lower in treatment unit 1, but about average again in treatment unit 2. My attitude in the classroom was much higher in treatment unit 1 and still fairly high in treatment unit 2. Overall, my attitude was more positive in the treatment units than it was in the nontreatment unit. These data are very

consistent with that of classroom observations and the daily journaling. It should be noted that all of the data presented on this project question, as well as every other project question discussed in this section, has been triangulated.

INTERPRETATION AND CONCLUSION

The main focus of this study was to determine whether differentiation, with respect to multiple intelligences, would increase student understanding. The data presented indicates that this type of differentiation does correlate to an increase in how well students understand the content. The students had better test scores, were able to explain concepts more thoroughly, and perceived themselves to have learned more than they would in a traditional classroom. The students also had much more success in the areas of data collection, analysis, and graphing. The data indicate that students were able to collect more accurate data, correctly graph that data, and then analyze the graphs of that data to find meaning between the two variables being tested.

In addition to content and laboratory skills, how engaged students were in the curriculum was also considered. The data gives good indication that this method of differentiation has very positive impact. Throughout both treatment units, the students were on task more often and put more effort into their assignments. It is questionable as to whether differentiation has an effect to how appropriately challenged the students are. The data seem to indicate that a different factor other than differentiation may be causing a greater effect on how challenging the material actually is, presumably the actual content being taught. However, it also appears that even when the teacher perceived the students to be struggling with more challenging content, the students themselves perceived the material to be less challenging. This may indicate the differentiation process causes students to perceive that the content is less challenging.

Both the attitudes of the students and the teacher were important factors to consider, as education should be an enjoyable process on behalf of both parties. The data indicated differentiation having a positive effect on the students' attitudes. They had an overall better demeanor and had much more fun with both the subject and each other. This method of differentiation also had an effect on the teacher's attitude. While there was a transition period that caused extra stress and frustration due to an increase in the amount of time spent planning, this went away as the process became more familiar and planning became more efficient. That withstanding, due to all of the success the students were having, being in the classroom and teaching became much more exciting. Overall, the entire process was very enjoyable for me.

While this project was very successful, if repeated again in the future there are a couple of changes that I would make. When analyzing the concept maps, it was difficult to quantitatively see growth because words used and number of words used each unit was different. In addition to that, there was no standard score to form a percentage out of, meaning that the score a student received from their map in unit could not be compared one from another unit. To remedy this, I also created a map using the same words the students had, and used that as the standard score to base a percentage off of. This whole process seemed a little crude and subjective. If used again for quantitative purposes, I would need to find a different way for comparison. I found that the observations provided much great data, but there was only one in each unit. While practically it can be difficult to get a colleague to observe you much more, multiple colleague observations per unit would be a great benefit.

VALUE

This study has caused me to shift the way I approach designing a lesson. Sometimes it is easy to forget that being a good teacher means more than just knowing what information to present and in what order to do so. It is important to consider the method being used to present it, and how to allow each student the chance to maximize their success in your classroom by ensuring that their needs, learning style, or intelligence is specifically addressed. The students have also come away with the idea being smart is not an all or nothing thing, but there are many different students who are better and worse at different things and that it is important that they use their strengths to help them succeed in areas they are weaker in.

This form of differentiation is universally useful throughout secondary education. Regardless of the course, there will always be different aspects of the same content that different students will be better or worse at because of a stronger or weaker intelligence in that area. Writing an English paper is not just verbal/linguistic, but logical in the presentation of arguments, interpersonal when comparing two people's viewpoints, and visual/spatial in the formatting of the paper so it looks professional. As differentiation is a popular method being instituted by a number of secondary administrations, they should find that this specific form of it would be easy to use and is very successful.

While this study has shown there are many benefits this method of differentiation has to offer, more work can be done. Much of what was used in this study was done by taking a combination of two theories, differentiation and Gardner's multiple intelligence theory, and putting them together. The amount of success should indicate that more

research should be done to formalize this form of differentiation as a method of education in general, not just in a freshman physics class.

Personally, through this study I now have a greater understanding and appreciation for what it is to be an excellent teacher. I have found myself being pushed more and becoming more of a professional in the fields of education. I have enjoyed this and would recommend the action research process to all teachers who want to make an effective change in their classrooms.

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APPENDICIES

APPENDIX A

HOWARD GARDNER'S EIGHT MULTIPLE INTELLIGENCES THAT ARE BEING
CONSIDERED

- **Linguistic intelligence** involves sensitivity to spoken and written language, the ability to learn languages, and the capacity to use language to accomplish certain goals. This intelligence includes the ability to effectively use language to express oneself rhetorically or poetically; and language as a means to remember information. Writers, poets, lawyers, and speakers are among those that Gardner sees as having high-linguistic intelligence (Smith, 2002, 2008).
- **Logical-mathematical intelligence** consists of the capacity to analyze problems logically, carry out mathematical operations, and investigate issues scientifically. In Gardner's words, it entails the ability to detect patterns, reason deductively and think logically. This intelligence is most often associated with scientific and mathematical thinking (Smith, 2002, 2008).
- **Musical intelligence** involves skill in the performance, composition, and appreciation of musical patterns. It encompasses the capacity to recognize and compose musical pitches, tones, and rhythms. According to Gardner, musical intelligence runs in an almost structural parallel to linguistic intelligence (Smith, 2002, 2008).
- **Bodily-kinesthetic intelligence** entails the potential of using one's whole body or parts of the body to solve problems. It is the ability to use mental abilities to coordinate bodily movements. Gardner sees mental and physical activity as related (Smith, 2002, 2008).
- **Spatial intelligence** involves the potential to recognize and use the patterns of wide space and more confined areas (Smith, 2002, 2008).

- **Interpersonal intelligence** is concerned with the capacity to understand the intentions, motivations and desires of other people. It allows people to work effectively with others. Educators, salespeople, religious, and political leaders and counselors all need a well-developed interpersonal intelligence (Smith, 2002, 2008).
- **Intrapersonal intelligence** entails the capacity to understand oneself, to appreciate one's feelings, fears, and motivations. In Howard Gardner's view, it involves having an effective working model of ourselves, and to be able to use such information to regulate our lives (Smith, 2002, 2008).
- **Naturalist intelligence** enables human beings to recognize, categorize, and draw upon certain features of the environment. It combines a description of the core ability with a characterization of the role that many cultures value (Smith, 2002, 2008).

APPENDIX B

MULTIPLE INTELLIGENCE INVENTORY AND RUBRIC

Name _____ Date _____

Period _____

Multiple Intelligence Inventory

Please read each statement, and if that statement is true, then place an X on the line.

1. ___ People often ask me the meaning of words
2. ___ I can think in abstract, clear, imageless concepts
3. ___ I always know north from south no matter where I am.
4. ___ I'm good at finding the fine points of word meanings.
5. ___ I remember more when I listen to the radio or a CD than from television or movies
6. ___ I enjoy word games such as crossword puzzles, Scrabble, and Boggle.
7. ___ I enjoy visual puzzles such as mazes, jigsaw puzzles, 3-D images
8. ___ I often see patterns and relationships between numbers faster and easier than others.
9. ___ I wonder about how some things work and keep up-to-date on new scientific developments
10. ___ I'd like to study the structure and logic of languages.
11. ___ I like to work with numbers and figures.
12. ___ I can find logical flows in things people say and do at work or home
13. ___ I really enjoy books
14. ___ I can look at an object one way and see it sideways or backwards just as easily.
15. ___ I enjoy Math and Science in school
16. ___ I like to ask "what if" questions (example: "What if I fertilized my plants twice as often?")
17. ___ It's easy to imagine what something would look like from a bird's eye view
18. ___ I always understand the directions that come with new gadgets or appliances.
19. ___ I often draw or doodle
20. ___ I'm good at adding and multiplying in my head (example: triple the ingredients of a recipe).

21. ___ I like puns, tongue twisters, nonsense rhymes, and double meanings
22. ___ I look for structure, patterns, sequences, or logical order
23. ___ I often refer to things I have read or heard in conversations
24. ___ I'm responsive to color
25. ___ English, Social Studies, and History are easier subjects for me than Science and Math
26. ___ I believe that there is a rational explanation for almost everything
27. ___ I'd rather draw a map than give someone verbal directions.
28. ___ I enjoy a good lecture, speech or sermon.
29. ___ I like to work puzzles and play games.
30. ___ When I close my eyes, I can see clear visual images
31. ___ It's easy for me to say what I think in an argument or debate.
32. ___ I have vivid dreams at night
33. ___ I like to work with calculators and computers.
34. ___ I prefer reading books, newspapers and magazines that have many illustrations
35. ___ Just looking at shapes of buildings and structures is pleasurable to me.
36. ___ I like solving brainteasers, logical games and other strategy games such as chess/checkers
37. ___ I navigate well in unfamiliar places
38. ___ I hear words in my head before I write, read or speak them
39. ___ I enjoy writing detailed letters to friends.

Multiple Intelligence Inventory Scoring Rubric

- Student name:
- Date:

Verbal/Linguistic	Logical/Mathematical	Visual/Spatial
1	2	3
4	8	7
5	9	14
6	11	17
10	12	18
13	15	19
21	16	24
23	20	27
25	22	30
28	26	32
31	29	34
38	33	35
39	36	37
total	total	total

- Primary Intelligence:
- Secondary Intelligence:
- Tertiary Intelligence:

APPENDIX C

NONTREATMENT SAMPLE LESSON PLAN

Sample Nontreatment Lesson

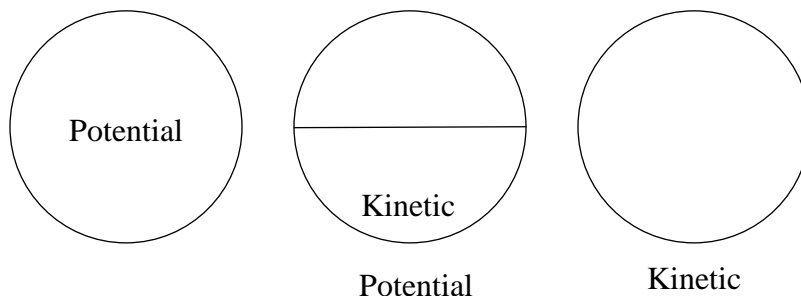
Conservation of Energy

Purpose: Student will be able to explain how the conservation of energy applies to an object whose energy is changing from potential to kinetic and vice versa.

Previous Knowledge: The students have previously defined potential and kinetic energy independent of each other and have learned to calculate each from its equation.

Lesson: The class will begin with the students breaking into small lab groups. At their lab station each group will have a ramp, a car, a meter stick, and a photogate with timer. The students will pick a point near the top of their ramp from which they will later release their car from. Using the meter stick the students will measure the height of the ramp and put that in their lab notes. They will be given the mass of car as well to add to their notes. By placing a photogate at the very bottom of the ramp, and knowing the length of wing on the car that will pass through it, after releasing the car, they will calculate the velocity of car at the bottom of the ramp. They then use these three values to calculate the potential energy of the car at the top, and the kinetic energy of the car at the bottom. Comparing these two values the students should find that they equal to each other. This will lead into a class discussion about what happened to the potential energy, where the kinetic energy came from, and why these two values are the same. With guidance the class write a formal definition of the conservation of energy. We will then go through an example on the board of an object falling. After describing it words, the students will then be shown how to use energy pie charts as a way of keeping track of how the energy is being stored in the falling object, making special note that at any given time the size of the entire pie (total energy) has remained unchanged. Using this, we will conclude by solving a problem, where the velocity of an object at the bottom of its fall is known, and from that figure out how high up the object must have started.

Example of energy pie charts for a car rolling down a frictionless ramp from rest:



Concluding problem: A ball of mass 6 kg is dropped from an unknown height. If it has a velocity of 32 m/s when it hits the ground, a) find the amount of kinetic energy the ball had the moment it hit the ground, and b) using the conservation of energy, find the height the ball was dropped from.

APPENDIX D

TREATMENT UNIT 1 SAMPLE LESSON PLAN

Sample Treatment Lesson 1

Ohm's Law

Note: Due to the nature of differentiation, the class will split into three groups according to the individual students' intelligence strength. Each group will work on a separate assignment/lesson which will specifically correspond to that group's intelligence type. On day one the student would do the assignment that corresponded with their primary intelligence (phase 1), the second day, their secondary intelligence, and the third day, their tertiary intelligence (phase 2).

Visual/Spatial group: The purpose of this lesson will be for the students to create a graphical representation of Ohm's Law for three different resistors. The students are given the following information. 1) For any single resistor circuit, to double the amount of current flowing through it, the voltage would also have to be doubled. 2) The resistance for any resistor is defined as the amount of voltage required per amp of current flowing through it. And 3) You have three resistors each with a different amount of resistance. The students are also given three sheets of graph paper. First, based solely on the information from number 1), the students are to draw a Voltage vs. Current graph for any of resistors. The students are then told that if this graph they made was the middle resistor, using the information in number 2), what would the high and low resistor graphs look like? Using the other two pieces of graph paper draw them. The students are then asked to compare and contrast the three graphs, specifically addressing what differences in the slope might represent.

Logical/Mathematical: The purpose of this lesson is for the students to use pattern recognition to determine the equation for Ohm's Law, and then use that equation to solve problems. The students are given the following data table for three different circuits:

Circuit	Voltage (V)	Current (A)	Resistance (Ω)
1	1.5	0.075	20
2	9	1.8	5
3	4	2	2

Each circuit in the data table above has measurements for the amount of voltage, current, and resistance present. Using this data, the students will then find a pattern and create an equation that relates voltage, current, and resistance, such that it is true for all three

circuits. Once complete the students will then be given problems to solve using this new found equation ($V=IR$).

Example Problems:

1. A circuit has a voltage of 6V and a resistance of 2Ω , solve for the amount of current.
2. Two nine volt batteries are hooked into a circuit that is required to produce at least four amps of current, what is the largest resistor that could be placed into the circuit to still produce this?
3. A man has a 4Ω resistor and a 12Ω resistor. A) If he puts the same 24 volts in to each (one at a time), which will have more current and how many times more? B) If he wanted to create two circuits each that produced exactly 3 amps, which resistor would require the higher voltage battery and how many times larger would the voltage be?

Verbal/Linguistic group: The purpose of this lesson will be for the students to conceptually understand Ohm's law by reading an article, summarizing it, and answering questions using the concepts from it. The students will be given an article on Ohm's Law (which can be found on the following page.) After reading the article, the students will then write a one paragraph summary of it. They will then exchange summaries, and edit each other's specifically looking for important aspects of the article which they believe may have been left out. The students will then be given conceptual questions about Ohm's which they will write responses to.

Conceptual Questions:

1. If a scientist were to replace a 1.5 volt battery in a circuit with a 9 volt battery, explain the effect this would have on the amount of current in the circuit. What information did the article give you to allowing you to answer this question?
2. If the wire in a circuit were to be heated up to very high temperature, a) how would that affect the resistance in the circuit, and b) how would that subsequently affect the amount of current in the circuit?
3. A woman bought a faulty hairdryer such that when she plugged it in a short circuit was created. Using Ohm's Law, and what you know from your own personal experiences, explain why this caused all of the lights to go out in her house.

Georg Ohm and Ohm's Law

Electrical Resistance, Voltage, and Electric Current in Circuits



Georg Ohm - Public Domain - Artist Unknown

In electrical circuit elements the resistance in ohms, potential difference in volts, and current in amps are related by Ohm's law.

Georg Simon Ohm

Georg Simon Ohm (1789 - 1854) first investigated the relationship between the current in an electric circuit element and the electrical potential difference, often called voltage, across the circuit element. Some sources list his birth year as 1787.

Ohm was born in Erlanger, Bavaria, now part of Germany. Though not formally educated himself, Ohm's father, a locksmith, encouraged his son to get the best possible education.

While working as a teacher Georg Ohm investigated electric currents and discovered the law now bearing his name. He published his work in an 1827 book, *Die galvanische Kette, mathematisch bearbeitet* (The Galvanic Circuit Investigated Mathematically), which was poorly regarded at the time. Modern physicists regard Ohm's work as important to our understanding of electric circuits.

Ohm's Law

For a circuit or circuit element, Ohm's law mathematically relates the current, the voltage, and the electrical resistance. The voltage is more properly called the electrical potential difference, but voltage is often used because it is less of a mouthful.

Ohm found that in a circuit the voltage and current are directly proportional to each other. This means as the voltage of a circuit is increased; the current will also increase by the same factor. This is true so long as the resistance in the circuit is held constant. Should the voltage be held constant, there is an inverse relationship between current and resistance in the circuit. The voltage or electrical potential difference, V , is measured in volts. The electrical current, I , is measured in amperes, commonly called amps. The resistance, R , is measured in ohms, which are volts per amp.

Ohm's Law is Not a Fundamental Law

Many laws of physics, such as Conservation of Energy, are fundamental laws that always apply without exception. Ohm's law is not one of these laws. It is an empirical law, found by experiment, that works pretty well most of the time. There are times however where Ohm's law does not work.

One example is an incandescent light bulb. The tungsten filament in the bulb does not follow Ohm's law. As the voltage in the wire filament increases it heats up. The resistance of a wire changes as its temperature changes. Hence the graph of the current and voltage in the wire will curve. The light bulb filament violates Ohm's law. Often if extreme currents are applied to wires, they heat up, change their resistances, and violate Ohm's law.

Ohm's Law and Short Circuits

When a short circuit occurs in an electrical appliance, most of the circuit for the appliance is bypassed. Hence the resistance becomes very low. The appliance may have a high electrical resistance, but the wire leading to the appliance does not.

By Ohm's law, the very low resistance in a short circuit causes a very high current. This high current blows the circuit breaker or fuse. If circuits did not have fuses or circuit breakers, high currents in the circuits could heat the wires to the point of starting a fire. Fuses and circuit breakers are therefore protective devices.

Ohm's law is a useful relationship between the voltage, current, and resistance in an electrical circuit.

APPENDIX E

TREATMENT UNIT 2 SAMPLE LESSON PLAN

Sample Treatment Lesson 2

Coulomb's Law

Note: Prior to this lesson, the students will have already completed phase 1 and phase 2 where they would have learned Coulomb's Law, first in their primary intelligence, then in their secondary, and finally in their tertiary. This lesson is phase 3, where the students complete a project with a group made up of students from different primary intelligence strengths.

Purpose: The students will demonstrate their understanding and knowledge of Coulomb's Law by creating the plans for a hypothetical electrostatic amusement park ride.

Lesson: The students are split into small groups where each group has at least one member of each primary intelligence strength represented. The groups will need to design an amusement park ride that is based on Coulomb's Law. The students are given all of the creativity they would like, as there are no rules with regard to practicality. Their ride must contain 2 places where there is a repulsive force, and 2 places where there is an attractive force. They are given a total of five charges to place anywhere on their ride where they would like. Each group is given five different amounts charge, three will be one polarity, and two will be the other. In the designing of their ride, they will need to complete the following: 1) At any location where two charges are near each other, they will have to describe the behavior of their ride with respect to the electrostatic force either being attractive or repulsive and why. 2) The diagram must be scaled and contain distances. At each of the four electro static interactions, they will have to pick a spot with a known distance between the two charges and calculate the amount of force present. 3) Using their knowledge of the direct relationship between electrostatic force and charge, and the inverse square relationship between electrostatic force and distance, they will then have to attempt to find the place on their ride where the greatest force is created and explain why they chose that location. They will then turn in the written description of their ride, the diagram of their ride, and relevant answers and calculations to the posed questions. This project forces the students to take what they have learned about Coulomb's Law in each of three different intelligences, and use them together to create a single complete project.

APPENDIX F
DAILY JOURNAL

Date _____ Period _____

Journal Prompts

- Focus Question: Understanding Physics Concepts
 - How well did the students understand the content today? 1 2 3 4 5
Explain and give examples from class to back up the chosen score:

- Subquestion 1: Student Engagement
 - How engaged were the students in the material? 1 2 3 4 5
Explain and give examples from class to back up the chosen score:

- Subquestion 2: Each Student Appropriately Challenged
 - How well was each student appropriately challenged from the lesson and material today? 1 2 3 4 5
Explain and give examples from class to back up the chosen score:

- Subquestion 3: Student Attitude and Motivation
 - How were the attitudes and motivations of the students? 1 2 3 4 5
Explain and give examples from class to back up the chosen score:

- Subquestion 4: Students Ability to Collect Data
 - Did the students have any specific difficulties in lab (collecting data, analyzing data, graphing, etc.)?

- Subquestion 5:
 - How well did the lesson go today?

 - What things went well today?

 - Were there any things that could have been improved upon?

 - How did the planning of the lesson go?

 - Other things that come to mind.

APPENDIX G

PRETESTS AND POSTTESTS

Name _____ Date _____

Period _____

Energy

1. Do either of the below statements correctly define energy? If so, which one/s?

Explain your reasoning.

- a. How much work an object can do each second
- b. A quantifiable property of an object that allows change to occur

Explain _____

2. Increasing which of the following will increase an object's kinetic energy?

Choose all that apply and explain your reasoning for doing so.

- a. mass
- b. height
- c. velocity
- d. temperature

Explain _____

3. An object is dropped off of a ladder. The moment before it hits the ground:

- a. the object has less energy than it did when it was dropped
- b. the object has the same amount of energy than it did when it was dropped
- c. the object has more energy than it did when it was dropped

Explain why this is so.

4. A 10 kg object hits the ground with a velocity of 10 m/s. About how high off of the ground was the object when it was dropped? Show work:

Equations:

—

5. Three students are asked to answer the following question: *If a 5 kg object is placed 10 m above the ground on Earth, and an identical one is placed at the same height above the surface of the moon, which has more potential energy and why?*

Student A claims: *“The one on the moon because gravity pulls less so it can go faster.”*

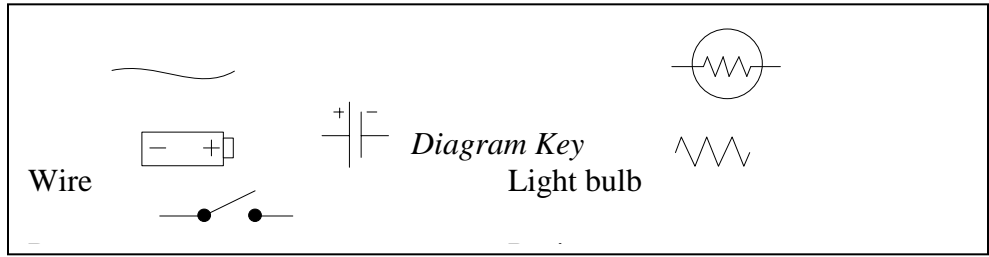
Student B claims: *“The one on Earth because objects have more mass on Earth than they do on the moon.”*

Student C claims: *“They both have the same because they have the same mass and are at the same height.”*

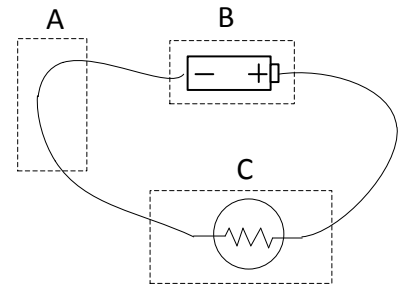
Which of the above students, if any, are correct? Explain your reasoning.

Name _____ Date _____
 Period _____

Electricity and Circuits



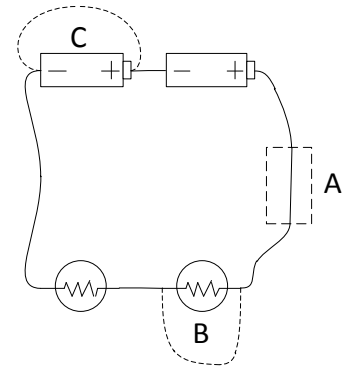
1. Of the boxed objects in the diagram to the right, which of them will act in the same manner as a resistor, and why?



2. Doing which of the following to the circuit below will make the overall circuit brighter? **Choose all that apply and explain your reasoning for doing so.**

- a. add a battery instead of wire A
- b. add a light bulb instead of wire A
- c. remove light bulb B and add a wire
- d. remove battery C and add a wire

Explain _____

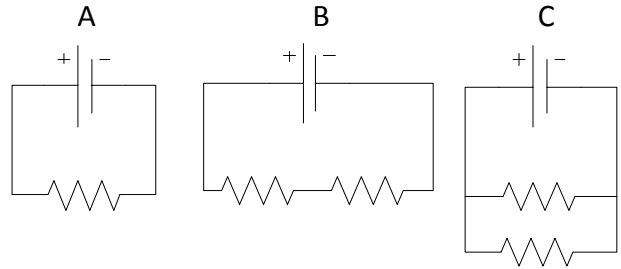


3. For a circuit to have 6 Amps of current and a total resistance of 3 Ohms, what voltage is required? Show all work.

4. Rank the following three circuits from **smallest to largest total resistance** and explain why. Assume all resistors are equal.

Rank: _____

Explain: _____

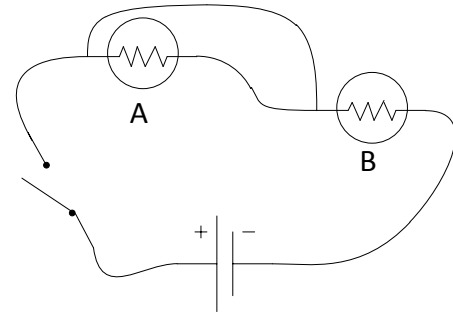


5. Three students are given the following question: *In the diagram below both bulbs are off while the switch is in the off position as shown. What will happen when the switch is turned to the on position and why?*

Student A claims: “A and B will both turn on and have the same brightness because they are in parallel.”

Student B claims: “Only bulb B goes on because of a short circuit.”

Student C claims: “Both lights go on but B will be brighter than A because it will get twice as much current as A”



Which of the above students, if any, are correct? Explain your reasoning.

Name _____ Date _____
Period _____Electrostatics

1. *When I rub a balloon against my head it becomes negative due to charging by _____ blank 1 _____, then it sticks to a wall because of charging by _____ blank 2 _____.*

On the lines below write the word that could be filled into each blank spot respectively to show what method of charging is being used, and then state the definition of that method.

Blank 1: _____ Definition:

Blank 2: _____ Definition:

2. *A positive charge is defined as an object that is made up of only protons.*
Does the above sentence correctly define positive charge? If so, explain why this must be true. If not, provide an example of a positive charge that does meet this definition and explain your reasoning.

3. Which of the following will be attracted towards each other? **Choose all that apply and then explain your reasoning.**
- Two protons.
 - Two electrons.
 - A proton and an electron.

Explain _____

4. Two charges are some distance apart. Given that the equation for Coulomb's law is $F_e = k \frac{q_1 q_2}{r^2}$ (where F_e is electrostatic force, k is a constant, q is charge and r is distance), in order to double the force between the charges, the distance should be changed by a factor of what? (*ex. changing by a factor of 3 would mean tripling the current distance, changing by a factor of 1/5 would mean changing to one fifth of the original distance*)

Answer _____

Explain your reasoning for your answer:

5. Three students are given the following question. *John stands on top of 10 meters of metal scaffolding, whereas Mary stands on 10 meters of Styrofoam. Both are out in the same lightning storm. Who is more likely to get hit by lightning and why?*

Student A claims: "*John, because metal acts as an insulator*"

Student B claims: "*Mary, because Styrofoam acts as a conductor*"

Student C claims: "*They would have the same chance because they are both at the same height and the material under them will not make difference.*"

Which of the above students, if any, are correct? Explain your reasoning.

APPENDIX H

INTERVIEW QUESTIONS

Post-Nontreatment (Energy) Unit Interview Questions

1. **(Focus Question)** Given the following terms (the student will be given the terms on individual pieces of paper that they can and will be encouraged to manipulate): energy, conservation of energy, kinetic energy, potential energy, work, mass, velocity, height, gravity, force, and distance, arrange them in such a way that shows how they are related to each other and explain why you chose that setup. Please think out loud as you arrange the terms and add in connecting words. (The word “energy” will be given to the student as the most general term)
2. **(Subquestion 1)** Did you find that this unit kept you engaged? Was it the activities or the content? What parts were more engaging, and which parts were less? What about them kept you engaged or made you less engaged? Why was that?
3. **(Subquestion 2)** How challenging did you find this unit to be? Was the content challenging? Why? Could the material have been presented differently to make it more or less challenging? Do you feel that this was as challenging as a 9th grade class should be, or was it too hard or too easy? Why?
4. **(Subquestion 3)** Do you enjoy coming to physics class? Why (not)? What parts of the class do find most enjoyable? Are there any parts of class that you particularly do not enjoy? What are they? Why are they not enjoyable? Do you have any suggestions on how class could be more enjoyable?
5. **(Subquestion 4)** Consider the data below:

Velocity (m/s)	Kinetic Energy (J)
1	0.5
2	2
3	4.5
4	8

What tools could you use to analyze this data? (How could you figure out what this data is telling us about how velocity and kinetic energy are related?)

Create a graph. Explain to me how you are creating the graph. What does the graph tell you? How does the graph show how velocity and kinetic energy are related? What would mean if the line was straight instead?

Student _____ Date _____

Post-Treatment 1 (Electricity/Circuits) Unit Interview Questions

1. **(Focus Question)** Given the following terms (the student will be given the terms on individual pieces of paper that they can and will be encouraged to manipulate): electrical circuits, Ohm's Law, voltage, current, resistance, simple circuit, series circuit, parallel circuit, light bulb, battery, and wire, arrange them in such a way that shows how they are related to each other and explain why you chose that setup. Please think out loud as you arrange the terms and add in connecting words. (The term "electrical circuits" will be given to the student as the most general term[.])
2. **(Subquestion 4)** Consider the data below:

Current (A)	Voltage (V)
0.5	1.5
1	3
2	6
3	9

What tools could you use to analyze this data? (How could you figure out what this data is telling us about how current and voltage are related?)

Create a graph. Explain to me how you are creating the graph. What does the graph tell you? How does the graph show how current and voltage are related? What does it mean that the line is straight? What does the slope tell us? How do you know?

Student _____ Date _____

Post-Treatment 2 (Electrostatics) Unit Interview Questions

1. **(Focus Question)** Given the following terms (the student will be given the terms on individual pieces of paper that they can and will be encouraged to manipulate): charges, positive, negative, neutral, like, opposite, attract, repel, charging, friction, conduction, induction, Coulomb's Law, Force (F_e), charge (q), distance (r), conductor, and insulator, arrange them in such a way that shows how they are related to each other and explain why you chose that setup. Please think out loud as you arrange the terms and add in connecting words. (The term "charges" will be given to the student as the most general term)
2. **(Subquestion 1)** Did you find that this unit kept you engaged? Was it the activities or the content? What parts were more engaging, and which parts were less? What about them kept you engaged or made you less engaged? Why was that?
3. **(Subquestion 2)** How challenging did you find this unit to be? Was the content challenging? Why? Could the material have been presented differently to make it more or less challenging? Do you feel that this was as challenging as a 9th grade class should be, or was it too hard or too easy? Why?
4. **(Subquestion 3)** Do you enjoy coming to physics class? Why (not)? What parts of the class do find most enjoyable? Are there any parts of class that you particularly do not enjoy? What are they? Why are they not enjoyable? Do you have any suggestions on how class could be more enjoyable?
5. **(Subquestion 4)** Consider the data below:

Distance between two charges (m)	Electrostatic Force felt by each charge (N)
1	64
2	16
4	4
8	1
16	0.25

What tools could you use to analyze this data? (How could you figure out what this data is telling us about how the distance and electrostatic force between two charges is related?)

Create a graph. Explain to me how you are creating the graph. What does the graph tell you? How does the graph show how distance and electrostatic force are related? What is the nature of this relationship?

6. For the last two units (treatment units), the instruction has been differentiated based upon your intelligence strengths. How do you feel your understanding of the material in these units compares to when the instruction was not differentiated such as during the energy unit (nontreatment unit)? Given the option, would you rather use the differentiated instruction, or the nondifferentiated instruction, why? Was there anything in particular that you found you really enjoyed or really helped you during these past two units, if so what were they? What about them made them enjoyable or helped you? Was there anything in particular that you found you really disliked or found to be frustrating during these past two units, if so what were they? What about them did you like dislike or frustrate you?

APPENDIX I
STUDENT SURVEYS

Name _____ Date _____

Period _____

Preunit Nontreatment Survey (Energy Unit)

1. On a scale of 1 to 5, how would you rank your current understanding of energy, where 1 would be not being sure what energy is, 3 being a decent understanding of what energy is and how it works, 5 being understanding energy completely and able to teach/explain it to others.

Why did you choose that number?

If you had to attempt to give a one sentence definition of energy, what would it be?

Are there any other facts about energy that you know that you think are important, if so, what are they?

2. We are about to start a unit which will explore the concepts of energy in general, as well as specifically look into a couple types of mechanical energy (kinetic and potential energy) and look at them conceptually, graphically, and mathematically. On a scale of 1 to 5, how difficult do you expect this unit to be, where 1 is extremely difficult (harder than it should be for a 9th grade class), 3 is about average difficulty (challenging, but the right amount for a 9th grade class), and 5 is very easy (not nearly challenging enough for a 9th grade class).

Why did you choose that number?

As stated, we will be looking at energy **conceptually** (definitions and being able to explain applications), **graphically** (using charts, diagrams and graphs and being able to create and explain them), and **mathematically** (using equations to solve problems and find numerical solutions). Which of these three aspects do you think you will have the most difficult time with and why?

Which of these three aspects do you think you will have the least difficult time with and why?

Name _____ Date _____
Period _____

Postunit Nontreatment Survey (Energy Unit)

1. On a scale of 1 to 5, how would you rank your current understanding of energy, where 1 would be not being sure what energy is, 3 being a decent understanding of what energy is and how it works, 5 being understanding energy completely and able to teach/explain it to others.

Why did you choose that number?

2. On a scale of 1 to 5, how difficult did you find this unit to be, where 1 is extremely difficult (harder than it should be for a 9th grade class), 3 is about average difficulty (challenging, but the right amount for a 9th grade class), and 5 is very easy (not nearly challenging enough for a 9th grade class).

Why did you choose that number?

3. On a scale of 1 to 5, how engaging did you find this unit to be? (By engaging, I am referring to how often you stayed on task and used the time given to complete the activities).

Why did you choose this number?

4. On a scale of 1 to 5, how would you rank your attitude toward this unit, where 1 is hating this unit, the way it was structured and it didn't help you learn, 3 is the structure had parts that you liked and others you didn't, and 5 is you really loved how this unit was structured and it really helped you learn.

Why did you choose that number?

Name _____ Date _____
Period _____

Preunit Treatment 1 Survey (Electricity/Circuits Unit)

1. On a scale of 1 to 5, how would you rank your current understanding of how electricity works in circuits, where 1 would be not being sure what electricity is, 3 being a decent understanding of what electricity, voltage, and current are, 5 being an in depth understanding of electricity, voltage, current, and resistance, as well as how each will behave in both series and parallel circuits.

Why did you choose that number?

If you had to attempt to give a one sentence definition of electricity, what would it be?

Are there any other facts about electricity or circuits that you know and think are important, if so, what are they?

2. We are about to start a unit which will explore the concepts of electricity and the properties of circuits (such as voltage, current, and resistance) and will look at them conceptually, graphically, and mathematically. On a scale of 1 to 5, how difficult do you expect this unit to be, where 1 is extremely difficult (harder than it should be for a 9th grade class), 3 is about average difficulty (challenging, but the right amount for a 9th grade class), and 5 is very easy (not nearly challenging enough for a 9th grade class).

Why did you choose that number?

As stated, we will be looking at electricity **conceptually** (definitions and being able to explain applications), **graphically** (using charts, diagrams and graphs and being able to create and explain them), and **mathematically** (using equations to solve problems and find numerical solutions). Which of these three aspects do you think you will have the most difficult time with and why?

Which of these three aspects do you think you will have the least difficult time with and why?

Name _____ Date _____
Period _____

Postunit Treatment 1 Survey (Electricity/Circuit Unit)

1. On a scale of 1 to 5, how would you rank your current understanding of how electricity works in circuits, where 1 would be not being sure what electricity is, 3 being a decent understanding of what electricity, voltage, and current are, 5 being an in depth understanding of electricity, voltage, current, and resistance, as well as how each will behave in both series and parallel circuits.

Why did you choose that number?

2. On a scale of 1 to 5, how difficult did you find this unit to be, where 1 is extremely difficult (harder than it should be for a 9th grade class), 3 is about average difficulty (challenging, but the right amount for a 9th grade class), and 5 is very easy (not nearly challenging enough for a 9th grade class).

Why did you choose that number?

3. On a scale of 1 to 5, how engaging did you find this unit to be? (By engaging, I am referring to how often you stayed on task and used the time given to complete the activities).

Why did you choose this number?

4. On a scale of 1 to 5, how would you rank your attitude toward this unit, where 1 is hating this unit, the way it was structured and it didn't help you learn, 3 is the structure had parts that you liked and others you didn't, and 5 is you really loved how this unit was structured and it really helped you learn.

Why did you choose that number?

5. How did this past unit, in which instruction was differentiated based on type of intelligence strength, compare to the previous unit on energy which was not?
6. Did you prefer the type of differentiated instruction in this past unit, or the traditional type of instruction in the previous energy unit? Please explain why.

Name _____ Date _____
Period _____

Preunit Treatment 2 Survey (Electrostatics Unit)

1. On a scale of 1 to 5, how would you rank your current understanding of electrostatics (how charged particles interact with each other), where 1 would be not being sure what a charged particle is, 3 being a decent understanding of positive and negative charge and Coulomb's Law, 5 being an in depth understanding of charge, its behavior in conductors and insulators, electric fields and how charges will behave in them, and Coulomb's Law.

Why did you choose that number?

If you had to attempt to give a one sentence explanation of what a charge is, what would it be?

Are there any other facts about charge or its behavior that you know and think are important, if so, what are they?

2. We are about to start a unit which will explore the concepts charge, and how it behaves in different materials and situations. You will look at them conceptually, graphically, and mathematically. On a scale of 1 to 5, how difficult do you expect this unit to be, where 1 is extremely difficult (harder than it should be for a 9th grade class), 3 is about average difficulty (challenging, but the right amount for a 9th grade class), and 5 is very easy (not nearly challenging enough for a 9th grade class).

Why did you choose that number?

As stated, we will be looking at electrostatics **conceptually** (definitions and being able to explain applications), **graphically** (using charts, diagrams and graphs and being able to create and explain them), and **mathematically** (using equations to solve problems and find numerical solutions). Which of these three aspects do you think you will have the most difficult time with and why?

Which of these three aspects do you think you will have the least difficult time with and why?

Name _____ Date _____
Period _____

Postunit Treatment 2 Survey (Electrostatics Unit)

1. On a scale of 1 to 5, how would you rank your current understanding of electrostatics (how charged particles interact with each other), where 1 would be not being sure what a charged particle is, 3 being a decent understanding of positive and negative charge and Coulomb's Law, 5 being an in depth understanding of charge, its behavior in conductors and insulators, electric fields and how charges will behave in them, and Coulomb's Law.

Why did you choose that number?

2. On a scale of 1 to 5, how difficult did you find this unit to be, where 1 is extremely difficult (harder than it should be for a 9th grade class), 3 is about average difficulty (challenging, but the right amount for a 9th grade class), and 5 is very easy (not nearly challenging enough for a 9th grade class).

Why did you choose that number?

3. On a scale of 1 to 5, how engaging did you find this unit to be? (By engaging, I am referring to how often you stayed on task and used the time given to complete the activities).

Why did you choose this number?

4. On a scale of 1 to 5, how would you rank your attitude toward this unit, where 1 is hating this unit, the way it was structured and it didn't help you learn, 3 is the structure had parts that you liked and others you didn't, and 5 is you really loved how this unit was structured and it really helped you learn.
-

Why did you choose that number?

5. How did this past unit, in which instruction was differentiated based on type of intelligence strength, compare to the previous unit on energy which was not?
6. Did you prefer the type of differentiated instruction in this past unit, or the traditional type of instruction in the previous energy unit? Please explain why.

APPENDIX J

OBSERVER PROMPTS

3. Throughout the lesson please note individual teacher behaviors with respect to his attitude and engagement. For each behavior noted, please identify a) what the behavior is, b) whether it indicates a good or poor attitude or engagement, c) the current activity at the time of the behavior, and d) apparent causes of the behavior (i.e. students not understanding the material, students misbehaving, students asking good questions, etc.)

4. On a scale of 1 to 5, how would you rate the teacher's overall attitude toward planning and teaching this lesson? (1 being a very poor attitude, and 5 being highly elated by the process.)

Cite examples from the lesson, classroom or teacher to explain why you chose the above score.

5. Are there any other comments or things of note that you feel should be mentioned?

APPENDIX K
PERSONAL SURVEY

Date _____ Unit _____

Personal Survey

1. How much time did I spend planning and grading activities for this unit?
2. Does this personally feel like a lot of time, a little, or a normal amount?
3. On a scale of 1 to 5, how happy am I with the amount of time spent planning and grading, where 1 is very unhappy, 3 is indifferent, and 5 is very pleased.

4. How do I feel about differentiation in general, is this something I still want to do?
5. How do I feel the students are responding to the unit at hand?
6. On a scale of 1 to 5, how happy was I teaching this unit, where 1 is very unhappy, 3 is indifferent, and 5 is very pleased.

7. Explain reasoning for choice in question 6.

APPENDIX L
TIMELINE

Basic Overview Timeline of Data Collection

- 12/1/2010
 - Administer Multiple Intelligence Inventory
- **Start Project Implementation: December 2, 2010**
- *12/3/2010 to 12/17/2010*
 - Administer nontreatment pretest, and preunit survey
 - Energy Nontreatment Unit
 - Have observer come in
 - Daily journaling
 - Analysis of student work
 - Administer nontreatment postunit survey, interview and posttest
 - Take end of unit personal survey
- *1/17/2011 – 2/4/2011*
 - Administer treatment unit 1 pretest, and preunit survey
 - Electricity and Circuits Treatment Unit 1
 - Have observer come in
 - Daily journaling
 - Analysis of student work
 - Administer treatment unit 1 postunit survey, interview and posttest
 - Take end of unit personal survey
- *2/7/2011 to 2/25/2011*
 - Administer treatment unit 2 pretest, and preunit survey
 - Electrostatics Treatment Unit 2
 - Have observer come in
 - Daily journaling

- Analysis of student work
 - Administer treatment unit 2 postunit survey, interview and posttest
- **End Project Implementation: February 25, 2011**

APPENDIX M
CONCEPT MAP RUBRIC

Scoring Rubric for Concept Map

Map Component	Possible points	Awarded points	Special things noticed about map
Proposition			
Clear and meaningful to the central topic	2 each		
Beyond given set of terms	3 each		
Not properly linked	1 each		
Vague	1 each		
Branch			
Top	1		
Successive branches	3 each		
Levels of hierarchy (general to specific)	5 each level		
Cross Links	10 each		
Examples	1 each		
Total			
Overall reaction to map and special things noticed.			

APPENDIX N

DATA AND GRAPH ANALYSIS RUBRIC

Lab_____ Period____ Date_____

Qualitative rubric for student's data analysis and graphing technique (by class)
(Subquestion 4)

1. Overall, how well was the quantitative data graphed (axes correctly numbered, points correctly plotted from data table, etc.)?
2. Were the students able to state the trend of their data from either the graph or the data table directly? (specifically relating to whether the data was increasing or decreasing, and whether it was constant or changing)
3. How well were the students able to find the correct relationships between the variables in question?
4. Were there any other additional notes or features you found to be of note with respect to how the students were able to graph and analyze their data?