



Implementation of inquiry-based tutorials in an introductory physics course : the role of the graduate teaching assistant  
by Carol Wiggins Thoresen

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Education  
Montana State University  
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**Abstract:**

This study determined if the training provided physics teaching assistants was sufficient to accomplish the objectives of inquiry-based tutorials for an introductory physics course.

Qualitative research methods were used: (1) to determine if the Physics by Inquiry method was modeled; (2) to describe the process from the TA perspective; (3) to determine TA opinions on training methods; (4) to develop a frame of reference to better understand the role of TA's as instructional support staff.

The study determined that the teaching assistants verbalized appropriate instructional actions, but were observed to use a predominantly didactic teaching style. TA's held a variety of perceptions and beliefs about inquiry-based learning and how science is learned. They felt comfortable in the role of tutorial instructor. They were satisfied with the training methods provided and had few suggestions to change or improve training for future tutorial instructors.

A concurrent theme of teacher action dependent on teacher beliefs was sustained throughout the study. The TA's actions, as tutorial instructors, reflected their educational beliefs, student background and learning experiences. TA's performance as tutorial instructors depended on what they think and believe about learning science..

Practical implications exist for training teaching assistants to be tutorial instructors. Some recommendations may be appropriate for TA's required to use instructional methods that they have not experienced as students. Interview prospective teaching assistants to determine educational experience and beliefs. Employ inexperienced teaching assistants whose perspectives match the proposed instructional role and who might be more receptive to modeling. Incorporate training into staff meetings. Provide time for TA's to experience the instructional model with simulation or role play as students and as instructors, accompanied by conference discussion. Use strategies known to enhance adult learning and that are sensitive to the variability of adult learners. Educate for critical reflection. Incorporate a system of peer coaching. Include a teaching assistant training component in group process and group management.

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by

Carol Wiggins Thoresen

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April 6, 1994

To my family, Merrill, Merrilee, Richard and Helen.

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## ABSTRACT

This study determined if the training provided physics teaching assistants was sufficient to accomplish the objectives of *inquiry-based* tutorials for an introductory physics course.

Qualitative research methods were used: (1) to determine if the *Physics by Inquiry* method was modeled; (2) to describe the process from the TA perspective; (3) to determine TA opinions on training methods; (4) to develop a frame of reference to better understand the role of TA's as instructional support staff.

The study determined that the teaching assistants verbalized appropriate instructional actions, but were observed to use a predominantly didactic teaching style. TA's held a variety of perceptions and beliefs about inquiry-based learning and how science is learned. They felt comfortable in the role of tutorial instructor. They were satisfied with the training methods provided and had few suggestions to change or improve training for future tutorial instructors.

A concurrent theme of teacher action dependent on teacher beliefs was sustained throughout the study. The TA's actions, as tutorial instructors, reflected their educational beliefs, student background and learning experiences. TA's performance as tutorial instructors depended on what they think and believe about learning science.

Practical implications exist for training teaching assistants to be tutorial instructors. Some recommendations may be appropriate for TA's required to use instructional methods that they have not experienced as students. Interview prospective teaching assistants to determine educational experience and beliefs. Employ inexperienced teaching assistants whose perspectives match the proposed instructional role and who might be more receptive to modeling. Incorporate training into staff meetings. Provide time for TA's to experience the instructional model with simulation or role play as students and as instructors, accompanied by conference discussion. Use strategies known to enhance adult learning and that are sensitive to the variability of adult learners. Educate for critical reflection. Incorporate a system of peer coaching. Include a teaching assistant training component in group process and group management.

## CHAPTER 1

## INTRODUCTION AND LITERATURE REVIEW

Overview of the StudyIntroduction

Calls for changes in science teaching and learning abound. Current reforms, such as those articulated in the National Assessment of Educational Progress (1987), press to alter content and reformat instruction, to move toward the active engagement of students in inquiry, problem solving, real world applications and appropriate uses of technology. New instructional strategies are envisioned that rely less on memorization and established procedures and place more emphasis on conceptual understanding.

A frequent criticism of the educational system is that learning is fragmentary and too much concerned with acquisition of isolated bits of information (Perkins & Salomon, 1989). "It is a well known fact of learning theory that isolated, unassociated facts are the first to be forgotten. Even if they are retained, they may still be unattached to any body of knowledge and are therefore of limited value". (Hill, 1962, p. 28).

One effort to change mathematics and science teaching is the Systemic Teacher Excellence Preparation (STEP) Project. STEP is an

initiative designed to bring about large scale improvement in preparation of mathematics and science teachers in Montana, and to serve as a national model. One strand of the STEP project is university course revisions to model instructional strategies and promote student interest and learning. Montana State University's Physics 205 class was engaged in a STEP Project course revision, Fall, 1993. This introductory algebra-based physics class was a course requirement for secondary science education majors.

Teachers tend to "teach" with instructional methods familiar from their student days (Comeaux, 1991; Feinman-Nemser, McDiarmid, Melnick & Parker, 1987; Ziechner & Tabachnick, 1981; Brousseau, Brook and Byers, 1978; Lortie, 1975). While methods such as small group learning, discussion sessions, inquiry based approaches and problem solving experiences are currently being promoted, historically instruction has been predominantly in the lecture format. According to the 1980 *Current Issues in Higher Education* report - 83 percent of the faculty surveyed used lecture as the instructional method of choice (Eastern Michigan University, n.d.). In Goodlad's study of schooling (1984), two-thirds of class time was labeled teacher-centered, with classes engaged in discussion only five percent of the time.

This qualitative investigation studied the implementation of an inquiry-based instructional component in Physics 205. The study focused on graduate teaching assistants work as tutorial instructors: What was the teaching experience in Physics 205 like for them?

What did tutorial teaching mean to them? A detailed description and analysis of their interpretation of tutorial teaching was done.

Graduate teaching assistants had not experienced inquiry-based instruction as students and did not have teaching experience with student-centered instruction. The investigation (1) determined if the inquiry-based method of instruction was modeled by graduate teaching assistants, (2) described the tutorial instruction process from the perspective of the graduate teaching assistant, (3) determined the Physics 205 graduate teacher assistant opinions on training for tutorial instructors, and (4) developed a frame of reference to assist university faculty to better understand the role of graduate teaching assistants as instructional support staff in large introductory science classes.

### Present State of Science Teaching

The National Education Goals for the year 2000 call for United States students to be first in the world in science and mathematics achievement. The International Association for the Evaluation of Educational Achievement rated American youth low in mathematics and science skills. In a thirteen country study of high achieving science "specialists" - high school seniors -U. S. students placed last in biology, eleventh in chemistry and ninth in physics (Wolf, 1988, p. 165).

Data from the National Assessment of Educational Progress (NAEP) Report Card (1989) indicated the percentage of students in high school (age 17) who were at or above proficiency levels on higher order thinking skill was low - only 7% can infer relationships and draw conclusions using detailed knowledge (Baron, Forgione, Rindone, Kruglanski & Davey, 1989, p. 2). Schools are under pressure to improve student mathematics and science achievement.

The American Association for the Advancement of Science has stressed the need for a shift in emphasis from a curriculum dominated by emphasis on memorization of isolated facts and procedures, and proficiency with paper-and-pencil skills, to one which emphasizes conceptual understandings (Rutherford & Ahlgren, 1990).

Current reforms for changing science teaching and learning, such as those recommended in Science for all Americans (Rutherford & Ahlgren, 1990) and the National Science Teachers Association (1992, 1993), press for teachers to alter content and reframe science instruction. Teachers are encouraged to alter the structure of their classrooms to promote group interaction and discourse (Goodlad, Klein & Borwn, 1974; Cashin, 1985; Mortimer, 1985). A commitment exists to adopt the idea that learning is a constructive process and for significant change in curriculum and traditional teacher roles.

Education is a complex system with a tendency to revert to traditional form (Ahlgren & Rutherford, 1993, p. 20). Research by Glanz (1979), involved participant observation for one year as a full-

time student. Glanz concluded that the predominant instruction was essentially didactic, in a teacher-centered mode. The teacher organized and presented the content to the students, whose role was the absorption of that material (Glanz, 1979; Anderson & Smith, 1986).

Teachers, not policy makers or researchers, are called upon to make changes in content and pedagogy. However, teachers themselves are products and producers of the traditional instruction that the reformers seek to change (Gardner, 1991; Rutherford, 1990; Sizer, 1992; Sternberg, 1991; Wiggins, 1989). Teachers frequently 'teach as they've been taught' (Comeaux, 1991, p. 162). Teachers' understandings, attitudes, images, and assumptions have been shaped in traditional science classrooms with traditional conceptions of content, pedagogies, and ways of organizing students for instruction. What teachers do is what they know; what they have learned. Yet, current reforms require teachers to teach content in ways they have never experienced. This paradox is at the heart of the work of current science teacher reform.

Research Triangle Institute (Weiss, 1988) reports teacher training for science/mathematics has changed in the last decade with teachers spending more time lecturing classes and less time on hands on projects. Weiss reports that on any given day seventy percent of classes would be lecture "exactly contrary to what scientists and science educators recommend" (1988, p. 166).

Learning is a process of construction. Teachers and pre-service teachers construct understandings of teaching and learning, of subject matter and students as they themselves are schooled. Consequently, they will often reach conclusions, and develop practices different from those desired by teacher educators (Brown, Collins & Duguid, 1989). This presents a dilemma for teacher education committed to effecting particular changes in teaching practice.

#### Purposes of the Study

As a Research Assistant at Montana State University, the investigator became involved with the implementation phase of an inquiry-based instructional component for a first year college algebra-based physics class. This course was required for secondary science education students. Physics 205 was redesigned incorporating a plan to determine and build upon students' preexisting ideas and to promote greater understanding for the foundations of physics.

Students participated in ten two-hour inquiry based tutorials. These were small group discussion and problem solving sessions designed to challenge students' existing knowledge by creating a sense of "disequilibrium." Tutorials required students to use conceptual beliefs, rather than formulas, to solve problems. Students worked in small groups to reach consensus for solutions. This structure provided the opportunity to "wrestle with" explanations

which were designed to improve comprehension and retention for first year physics concepts.

The purposes of the study were (1) to describe the ways in which the *Physics by Inquiry* method was modeled by graduate teaching assistant actions in Physics 205 tutorial sessions, (2) to describe the tutorial instruction process from the perspective of the graduate teaching assistant, (3) to determine physics graduate student opinions on training methods for tutorial instruction, and (4) to develop a frame of reference which can be used by university faculty to better understand the role of graduate teaching assistants as instructional support staff in large undergraduate science classes.

#### Research Questions

1. Did graduate teaching assistants guide the student problem solving session by using appropriate questioning strategies?
2. How often did teaching assistants use direct instructional strategies?
3. Were teaching assistants sensitive to student learning frustration level during tutorials?
4. Did teaching assistants promote student group process?
5. What strategies did teaching assistants use to promote student group process?
6. What were graduate teaching assistants' perceptions of inquiry-based learning?

7. What were graduate teaching assistants' beliefs about how science is learned best?
8. How did graduate teaching assistants feel about their role as tutorial instructors.
9. Did graduate teaching assistants believe existing training met their needs?
10. Did graduate teaching assistants perceive a need for training?
11. Was there a graduate teaching assistant preference in method for in-service training?
12. What were the graduate teaching assistants' beliefs about their instructional role?
13. What methods of training were proposed for graduate teaching assistants by the graduate students?
14. Did graduate teaching assistants model appropriate instructional strategies in Physics 205 tutorial sessions after weekly training sessions?

Appendix A, summarizes research questions and related procedures and methods.

This study was planned to assist university science and mathematics course revisions dependent upon Graduate Teaching Assistants skill conducting inquiry based instruction. Student centered instruction for large university science courses presents considerable staffing problems. While Graduate Teaching Assistants were available, it was important to know if the training provided was sufficient to accomplish the goals of the tutorial project.

## Goals for Science Course Revision

### Research Base for Course Revision

Research suggests that students learn by constructing their own meaning of the experiences they have (Driver & Oldham, 1986; Sachse, 1989; Watson & Kronicek, 1990). This constructivist approach requires different methods for science instruction. Novak & Ridley (1988) believe that thirty-years of learning research can be condensed into one fundamental idea, known as Ausubel's

#### Assimilation Theory:

If I had to reduce all of educational psychology to just one principle, I would say this: 'the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly,' in other words, learners create new knowledge out of what they already know.  
(p. 6)

According to this theory, learners must actively pursue their own conceptual growth. Rote learning is characterized by arbitrary connections. It involves no interaction between what is learned and knowledge that the learner already possesses. Assimilation Theory involves the learner in an active quest to relate new knowledge to the relevant concepts and principles the student already has, called "empowering the learner" or "learning how to learn."

Novak (1988) calls the constructivist view:

...essentially an effort to integrate the psychology of human learning and the epistemology of knowledge construction. The key to this integration is that concepts and interrelated networks of concepts, or propositions, comprise the central elements in both knowledge production and human learning. Concepts are, if you will, the coin of meaning; they are what we think with and understand through. As human knowledge production can be described in terms of 'evolving populations of concepts,' so human learning can be charted in terms of changes in conceptual frameworks. Moreover, to claim that meaningful learning is conceptual is to suggest that new learning is facilitated by adequate and relevant concepts. (p. 6)

Students construct knowledge by interpretation of new experiences in the context of prior knowledge, experiences, episodes and images (Brown, Collins, & Druguid, 1989).

In The Case for Constructivist Classrooms, Brooks and Brooks (1993) describe the constructivist teacher as one who (1) encourages and accepts student autonomy and initiative; (2) uses raw data and primary sources, along with manipulative, interactive, and physical materials; (3) frames tasks by use of cognitive terminology such as "classify," "analyze," "predict," and "create;" (4) allows student responses to drive lessons, shift instructional strategies, and alter content; (5) inquires about students' understandings of concepts before sharing their own understandings of those concepts; (6) encourages students to engage in dialogue, both with the teacher and with one another; (7) encourage student inquiry by asking thoughtful, open-ended questions and encouraging students to ask questions of each other; (8) seek elaboration of students' initial responses; (9) engage students in experiences that might engender

contradictions to their initial hypotheses and then encourage discussion; (10) allow wait time after posing questions; (11) provide time for students to construct relationships and create metaphors; (12) nurture students' natural curiosity through use of the learning cycle model (pp. 103-116).

Concern for students' personal conceptions of how and why the natural world functions as an influence in mathematics and science teaching supported three international conferences at Cornell University. The proceedings focused on students' misconceptions in science and mathematics as well as teaching strategies intended to deal with those misconceptions (Novak, 1987a; Novak, 1987b; Novak, 1987c). The conferences generated 177 papers with topics representing the kind, number and tenacity of misconceptions, however, few papers dealt with educational strategies to mollify or remove the deleterious effects of misconceptions or limit teacher or text initiation of misconceptions (Novack, 1987c). The conferences defined the serious instructional problem of students' alternative framework or misconceptions as a limitation to learning science and mathematics.

The Cornell Conferences endorsed a constructivist epistemology both for clarifying the nature of knowledge and knowledge production, and as an underpinning for lesson planning and pedagogical practices. While the conference promulgates constructivist thinking for students, it reports that teacher education programs continue to give teachers fixed truths and methodologies,

rather than recognize the need to re-conceptualize subject matter and pedagogical strategies as they engage in the process of conceptual change.

Anderson & Smith (1986) suggest that conceptual change teaching can never be used without understanding what students are thinking, as it "involves classroom behavior ... and patterns of thought in which the teacher continually diagnoses student conceptions, considers where they are in the process of conceptual change, and acts accordingly" (p. 31).

Research suggests effective conceptual-change teaching depends on topic-specific knowledge of at least three different types: knowledge of content, knowledge of students, and knowledge of teaching strategies:

1. Knowledge of Content: sound knowledge of topic under study, including the most basic and important principles, the relationship of principles, how principles are related to other ways of understanding the world and students' understanding of real-world phenomena and how scientific conceptions explain them.

2. Knowledge of Students: how students typically respond to instruction, knowledge of student misconceptions in order to construct learning goals for conceptual change teaching, evaluation of changes in students brought about by instruction.

3. Knowledge of Teaching Strategies: teachers must make learning take place through use of appropriate teaching strategies and classroom activities which (a) diagnose student misconceptions

and monitor student progress, (b) use information to select activities that challenge student misconceptions, (c) introduce scientific content that promotes student understanding of scientific concepts (Anderson & Smith, 1986, p. 31).

While texts and teaching materials do not address misconceptions, Anderson and Smith (1986) found that some teachers change from didactic or discovery teaching to conceptual change teaching (p. 38). Changed teacher behavior was attributed primarily to introduction of new program materials, or teachers' own investigation of students' conceptions and how they could be changed to improve understanding of content.

The conceptual change perspective on learning has been the focus of many recent studies of science learning, for example Smith and Lott (1985) on photosynthesis; Clement (1982) on force and motion; Roth, Smith and Anderson (1983) on photosynthesis and food for plants; Smith and Anderson (1984) on plants as producers; Hollon and Anderson (1985) on heat and temperature; Anderson and Smith (1987) on light and color; Yaroch (1985) on equation balancing in chemistry; Heinze-Fry & Novak (1990) on concept mapping to enhance meaningful learning in Biology; Bishop and Anderson (1990) on natural selection and evolution; Hesse and Anderson (1992) on chemical change. These studies suggest a prevalence of students' naive conceptions persist and remain unchallenged by traditional didactic teaching.

A dramatic example of student understanding, or lack of understanding, is presented by Gardner's (1991) description of research with physics students. Physics students with high scores on standardized tests of physics knowledge and honor grades at the conclusion of a year of college physics were observed playing a game called Target. The researcher, Andrea DiSessa, devised the game, which is played in a computerized environment with a simulated object called a *dynaturtle*. The goal of the game, Target, is to give instructions to the *dynaturtle* so that it will hit a target. The game is simple enough so that both elementary children and college physics students approach it with enthusiasm and confidence. Yet nearly everyone at both levels of expertise fails dismally. Success at the game requires an understanding and application of Newton's laws of motion. Players must take into account the direction and speed of the *dynaturtle*.

DiSessa found a remarkable similarity between the strategies exhibited by 11- and 12-year old children and the university physics students studied. One MIT student, Jane, was a particularly adept physics student:

But what is remarkable is the fact that she did not, indeed for a time could not, relate the task (Target game) to all the classroom physics she had had. It was not that she could not make the classroom analyses; her vector addition was, by itself, faultless. It is more that her naive physics and classroom physics stood unrelated and in this instance, she exercised her naive physics. (Gardner, 1991, p. 153)

Gardner indicates that it would be wrong to draw excessive conclusions from the simple failure of one student to draw on formal training when confronted by a computer game. However, Jane's behavior turns out to be quite typical of what is found when students with training in physics or engineering are posed with problems outside the confines of class, what Gardner calls the "text-test context" (1991, p. 154).

Minstrell (1989, p. 144) summarized what cognitive research suggests for lesson design to foster conceptual development: (1) a preliminary phase where teacher and student identify students' existing ideas, possibly with pre-instruction quiz or diagnostic test at the beginning of a course; (2) a focusing phase to clarify the students' initial ideas, discussion after students record their initial ideas; (3) an activity or situation that challenges the students' initial ideas; and (4) an application phase, where students have the opportunity to practice using the new idea in multiple contexts. Student understanding of topics to be explored and student knowledge should provide a starting point for instruction.

Dewey believed that what we learn depends on the entire life experience, not just the manner of presentation:

We never educate directly, but indirectly by means of the environment. Whether we permit chance environments to do the work, or whether we design environments for the purpose makes a great deal of difference. And any environment is a chance environment so far as its educative influence is concerned unless it has been deliberately regulated with reference to its educative effect. (Dewey, 1966, p. 19)

Learning is not automatic from experiences. What matters is how experience is used.

In Making Connections: Teaching and the Human Brain, Caine & Caine (1991) suggest we are all immersed in complex experiences every moment of our lives. They recommend that teaching be designed to deliberately expand natural knowledge, that appropriate experiences with interactive elements are essential to this process. The three interactive elements recommended by Caine and Caine (1991) are: (1) *immersion* of the learner in complex experiences that are both "rich and real", (2) personally meaningful challenge or intrinsic motivation that is part of a state of mind identified as *relaxed alertness*, and (3) intensive analysis to gain insight, called *active processing of experience* (pp. 104-105).

One professor experimenting with instructional delivery is Eric Mazur, Gordon McKay Professor of Applied Physics at Harvard. Mazur now actively promotes an interactive method of teaching large lecture courses (Tobias, 1992). Mazur tested his students with an instrument designed to measure qualitative understanding of mechanics, the *Force Concept Inventory*. When he gave this conceptual understanding test to his class, a student asked, "Professor Mazur, how should I answer these questions? According to what you taught us, or by the way I *think* about these things?" (Tobias, 1992, p. 115) Mazur was alerted that a problem existed. He began interviewing students and made the observation that in discussion of a lab with one student, others would take the dialogue

further. This led to integration of discussion cycles into his lecture class.

Beginning in the fall of 1991, Mazur found or created five "thought" questions for each ninety-minute class. He shared his goal with students, he wanted them to "critically reason" about physics, not merely memorize equations. A ten- or fifteen-minute lecture is followed immediately by a conceptual multiple choice question to which students have a minute or so to record an answer and a confidence level ("pretty sure," "not quite sure," "just guessing"). Students then discuss the question and answer with their neighbor with the directions to convince their fellow student of their answer:

The single voice in an otherwise silent classroom is instantly transformed into a buzz of earnest discussion. Mazur watches and waits. After another minute his students record a second, possibly revised answer (and revised confidence level) on the same machine-readable sheet. Then there is a straw poll. If most have gotten the answer right, he moves on. If 40 percent or more got it wrong, he repeats the cycle on the same topic. (Tobias, 1992, p. 117)

The use of an interactive phase in lecture monitors student understanding and provides instructor feedback. Mazur believes in addition to breaking the monotony of passive lectures, this method improves the percentage of correct answers on conceptual examinations.

### Development of the Tutorials

The Physics Education Group at the University of Washington developed curriculum materials in conjunction with an extensive investigation of physics student conceptual understanding and reasoning difficulties (McDermott & Shaffer, 1992a). The group determined that success in solving quantitative problems was not a reliable measure of conceptual understanding (Trowbridge & McDermott, 1980; Trowbridge & McDermott 1981; Arons, 1982; Mazur, 1992). Students who could solve standard quantitative problems often could not answer simple qualitative questions based on the same physical concepts. This fact suggested the presence of underlying difficulties that apparently were not adequately addressed by traditional physics instruction (McDermott & Schaffer, 1992a, p. 995).

Each particular physics topic was systematically reviewed to acquire detailed knowledge about the conceptual and reasoning difficulties encountered by students. This research identified serious *misconceptions* common among students who have had instruction in the relevant material. The term *misconception* is used here to refer to an idea for which the student's interpretation is in conflict with the formal concept as understood by the physicist.

The methods used in this University of Washington research ranged from individual demonstration interviews conducted in a formal setting to descriptive studies carried out during instruction in

the classroom. In the individual demonstration interview, a simple demonstration was provided to serve as the basis for an investigator and student dialogue. Student progress was examined on a continuous basis over time with extended research in the form of classroom descriptions. Students involved in the investigation had a wide variation in physics background and were enrolled in a calculus-based or algebra-based introductory course.

Specific student difficulties were grouped into three general categories: (1) an inability to apply formal concepts, (2) an inability to use and interpret formal representations, and (3) an inability to reason qualitatively about behavior. In all interviews and tests, students were required to explain their answers. The design of effective instructional strategies for addressing specific difficulties required knowledge of the reasoning used. McDermott and Shaffer (1992a, p. 995) indicated that an error may be a symptom of a conceptual or a reasoning difficulty or of a combination of both.

If faulty reasoning is at the core of difficulty with a concept, focusing attention on the concept alone does not provide students with the assistance they need. Moreover, students may make the same apparent error for different reasons. Although short-answer responses can give an indication of how pervasive a particular error may be, they do not provide sufficiently detailed information to be helpful in curriculum development. Attention must be directed to the underlying cause, not merely to the symptoms. The meaning that students associate with a formal concept in physics is often very different from that which a physicist ascribes to that same concept. (McDermott & Schaffer, 1992a, p. 995)

Curriculum development followed this systematic investigation of student understanding, so that specific instructional strategies were developed to address specific difficulties. Designing, testing, modifying and revising the materials is done on a continuous cycle based on classroom experience by the Physics Education Group at University of Washington (McDermott & Shaffer, 1992b).

Curriculum development by the Physics Education group is based on the premise that meaningful learning will not occur unless students are engaged at a sufficiently deep intellectual level. The *Physics by Inquiry Model*, or the tutorial, encourages students to make the necessary mental commitment by guiding them through the process of constructing a conceptual model. Students are required to articulate their reasoning and apply it to predict and explain other behavior from the conceptual model.

In working through the inquiry model, students correct, on their own, many mistaken ideas. However, certain conceptual difficulties tend to persist. The Physics Education Group found that to help students overcome deeply rooted ideas is not simply a matter of telling them which mistakes to avoid. For significant conceptual change to occur, students have to become actively engaged in the learning process. McDermott and Shaffer summarize the sequence of steps as: *elicit, confront, resolve* (1992b, p. 1008). These steps do not define a single strategy but a continuum. Inherent in the instructional approach is the recognition that one encounter is never enough to overcome deep-seated conceptual difficulty. Students are

given multiple opportunities since certain misconceptions are so pervasive that they seem to be intuitive (McDermott & Shaffer, 1992b, p. 1009).

Recognizing that adoption of a laboratory based curriculum is not feasible in courses with large enrollments, the tutorial materials were developed for use in conjunction with lectures and textbooks. The major objective is to counter the passive learning environment of large lectures and to secure a mental commitment from students. The purpose is not to deliver additional information, but to help students deepen their conceptual understanding and develop skill in scientific reasoning.

#### Description of the Tutorials

The tutorial material consisted of units of related activities that focused on important elements of the standard physics curriculum. The carefully structured worksheets guided students through prescribed tasks that required explanations of reasoning. Students predicted the effect of specified changes in a system, observed and analyzed data, constructed interpretive graphs and diagrams, and solved problems that emphasized qualitative understanding.

The preferred learning environment for the activity was a small group of three or four students working together. Collaborative group learning was not a new method. The philosophical roots for construction of knowledge by interactive

group process is traced to the writings and influence of such philosophers and psychologists as John Dewey, George Kelly, George Herbert Mead, Thomas Kuhn, Jean Piaget, L. S. Vygotsky, and others (Comeaux, 1991, p. 152).

Collaborative learning was developed and explored in the 1950s and 1960s by a group of British secondary school teachers and by a British Biologist, M. L. J. Abercrombie, who was concerned with medical education (Comeaux, 1991, p. 152). This pioneer work with medical students established that skill with diagnosis is better learned when small groups of students work together. Some medical schools, such as Michigan State University, use curriculums centered on group problem solving. During the past ten years, collaborative group learning has gained popularity in college classrooms, particularly in writing programs.

Collaborative group learning is defined by Wiener as a "group's effort to reach consensus by their own authority" (in Comeaux, 1991, p. 153). It differs from other models of group work by placing an emphasis on how group consensus is negotiated and the placement of authority.

Tasks are structured so that the group must arrive at some common understanding and agreement about an answer. The process calls for 'intellectual negotiation,' and the requirement for consensus in a task creates a pressure that "leads students to take their ideas seriously, to fight for them, and to modify or revise them in light of other's ideas" (Comeaux, 1991, p. 153). How the group

arrives at the answer is important. The stress is on the students to learn from peers and share the construction of knowledge. The classroom is dominated by student thought and conversation rather than teacher thought and conversation.

In tutorial sessions the instructor is expected to act more like a facilitator of discussion than as a dispenser of knowledge (McDermott & Schaffer, 1992b, p. 1010). Instructors do not lecture, but circulate throughout the room while students work through exercises. A high instructor-to-student ratio allows the staff to engage students in dialogues that permit in-depth questioning.

Tutorials were designed with a system of pretests, a sample tutorial and tutorial pretest from Physics 205 are found in Appendix B. The pretests informed instructors about the level of student understanding prior to the tutorial experience and assisted students in identifying what they were expected to learn in the tutorial. Examinations provided a strong link to tutorials. Grading policy in the course supported the tutorials through content on the exams, requirements for attendance and post-tutorial homework submission.

### Assessment of the Tutorials

Assessment of tutorial materials was done with a short term study of 500 students at three different institutions. Four courses were involved: a lecture-based course with tutorials, a parallel

calculus-based course without tutorials at the University of Washington, a laboratory-centered calculus-based course at a liberal arts college and an algebra-based course at another university. There was a difference in the prevalence of certain errors between students at the University of Washington who had and had not participated in tutorial sessions (McDermott & Shaffer, 1992b, p. 1011). Fewer than 50% of the students in the two lecture-based courses without tutorials predicted correctly on conceptual questions, while more than 75% of the students in the course with tutorial sessions gave correct responses (McDermott & Shaffer, 1992b, p. 1011). Students from tutorial courses spent less time on traditional quantitative problem solving instruction, since concept development was the emphasis. However, quantitative scores were not adversely affected and may even improve as evidenced by results at the other institutions.

In a longer-term assessment, students from tutorial classes did somewhat better in arriving at numerical solutions under test conditions, even though their classes had spent more time on concept development and less time on problem solving. Students from the tutorial classes performed substantially better on all of the qualitative problems (McDermott & Shaffer, 1992,b, p. 1012).

Physics Tutorials for the Montana State University Physics 205 class were adapted from the Physics Education Group tutorials developed at the University of Washington. Physics 205 Tutorials followed the *Physics by Inquiry Model*. Tutorials were planned to

engage students at a sufficiently deep intellectual level to help the student develop meaningful, connected understandings. The aim was to allow students to interact and creatively find solutions to problems related to the recognized misconceptions that first year college physics students hold.

### Rationale for the Study

University teacher education students are provided models of instruction in science education methods classes that promote constructivist approaches with active engagement of students in inquiry, problem-solving and model building. Methods classes stress the need for relevant content, incorporation of appropriate technology and regular opportunities for social interaction and group work (Feinman-Nemser, 1992; Howey & Gardner, 1983). However, the science instruction, in university content classes, has tended to follow the lecture format (DeBoer, 1991; Weiss, 1988; Zeichner & Tabachnick, 1981). University students have few experiences with models of instruction recommended in science methods classes.

Future teachers use direct school experiences to learn the culture of schools. Zeichner and Tabachnick (1981, p. 8) report that most teacher "socialization" occurs through the internalization (largely unconscious) of teaching models during the time prospective teachers spend as students in close contact with teachers. Lortie (1975) made a similar observation: "There are ways in which being

a student is like serving an apprenticeship in teaching; students have protracted face-to-face and consequential interaction with established teachers" (p. 61).

Secondary science pre-service teachers are placed in a paradox: their vision of science teaching is being shaped by traditional science classes, while they are being told about preferred instructional strategies in education methods courses. It seems likely that they will begin their teaching careers modeling familiar pedagogy - "teaching is telling" (Lasley & Applegate, 1982).

Much of a pre-service teachers' ideas about learning, teaching, and knowledge, and their understanding of science is shaped by undergraduate experience in science content classes. To alter models of instruction used at the secondary level, it appears critical to redesign university science classes with various instructional strategies. If science instruction is to change, the next generation of science teachers require experiences in university content courses that model teaching strategies based on learning research.

Staffing is a major concern. To provide instruction, other than large lecture classes, requires a drastic change in staffing. Traditionally, graduate students hold assistantships as laboratory instructors. In this study, graduate students were asked to take a different responsibility. Graduate Teaching Assistants were instructional leaders in the inquiry-based tutorial program for Physics 205. This provided the instructional assistance needed to implement the tutorial method of instruction.

During the five years of the STEP Project, course revisions are planned for a series of courses in the Montana University system. The role of graduate students as teaching assistants is seen as a fundamental area of concern if different instructional strategies are to be implemented.

This study assisted university science course revisions dependent upon Graduate Teaching Assistants skill conducting inquiry-based tutorials. It was important to know if the training provided for graduate teaching assistants was sufficient to accomplish the goals of the tutorial project.

## Adult Learning

### Introduction

This section reviews characteristics of adult learners and theories of adult learning, since the physics graduate teaching assistants are adult learners. This section provides a foundation for discussion of tutorial instructor in-service training and implications for future graduate teaching assistant training.

### Variability of Adult Learners

Long (1990) emphasizes the variability of adult learners and suggests that no single profile for the adult learner exists (p. 25).

Rather than create an inadequate composite, Long provides overviews of selected physical characteristics of adult learners and describes psychological characteristics that have implications for understanding adult learners. Cognitive characteristics, personality characteristics, experiential characteristics and role characteristics must be recognized as contributing to the wide range of differences among adult learners (Long, 1990, p. 35).

In Transformative Dimensions of Adult Learning, Mezirow (1991) establishes a belief that the greatest oversight in adult learning theory is the failure to recognize the "central roles played by an individual's acquired frame of reference, through which meaning is construed and all learning takes place, and by the transformation of these habits of expectation during the learning process" (p. 4). The teacher of adults is especially challenged to be sensitive to the idiosyncrasies of each learner. Furthermore, educational and learning activities must be tailored to the special characteristics of each learner (Long, 1990, p. 36).

### Effectiveness of Learning Activities

In order to maximize effectiveness, learning activities need to be matched to program objectives. In his 1986 book, Helping Adults Learn, Knox describes survey results from coordinators of educational programs, that employers provide for their employees. The surveys ranked methods of learning activities matched to

program objectives (p. 81). For problem solving and application of new learning's to improved performance, the preferred methods were case study, simulation games, and conference discussion (Knox, 1986, p. 81).

### Role-Play Technique

To encourage exploration of alternative ways of thinking and acting, Brookfield (1987) encourages the use of role-playing technique that focuses on a central element in critical thinking - the ability to take on the perspectives of others. Brookfield believes it is difficult to understand the contradictions, ambiguities, conflicts and dilemmas of many situations from a purely intellectual level.

Role play brings to our consciousness some of the feelings and emotions involved with such contingencies. From role playing how people might react in typical situations, we are more likely to gain a fully rounded appreciation of the particular mix of thought processes, attitudes, perceptions, and emotions informing their actions. Role play is, therefore, invaluable as a prompt to perspective taking. It is also a useful training device that can help prepare for emotionally charged or interpersonally complex situations we will be involved in at some later stage. (Brookfield, 1987, p. 105)

### Conditions for Learning

Learning environments should enhance participants' commitment and interest by building supportive learning

environments. Knox (1986) makes the following setting and climate suggestions: select attractive facilities, help participants get acquainted, present yourself as a person, reduce apprehension, encourage active participation, provide an overview, obtain feedback, encourage return, be available, and review for planning (pp. 132-134).

Conditions of learning that are applicable to adult education have been synthesized in Long (1983, p. 244):

1. Learning requires motivation to change.
2. Active involvement of the learner promotes effective learning.
3. Learning depends on past experiences.
4. Learning effectiveness depends on feedback.
5. An informal atmosphere aids the learning process.

### Reflective Learning

Mezirow (1991) proposes that adult learners should be supported "to be self-guided, self-reflective, and established in communities of discourse in which these qualities are honored and fostered" (p 224). Mezirow calls this transformative learning which involves taking action to implement insights derived from critical reflection (p. 225).

Schon (1983) calls this process *reflection in action* and demonstrates how critical reflection is tied to personal and workplace change. Schon's critical reflection in action is an artistic

process: intuitive, improvisational and creative. Schon asserts that when faced with unexpected and unfamiliar situations requiring immediate response, reactions that might be perceived to be haphazard are often grounded in intuitive understanding of the field of practice and accumulated experience. Brookfield calls this theory in use (1987, p. 157). He would educate toward reflection to develop critical thinking to challenge adults to explore alternative ways of thinking and acting.

Kidd (1973) notes that in English we need a word, a noun, that means "he-who-assists-learning-to-happen," or "manager of learning," but we use the word teacher for lack of this term (p. 292). While there are no blueprints for teachers to stimulate and guide learning, there are many different roles the teacher assumes in the learning transaction. Kidd (1973, p. 293) lists these leadership actions associated with teaching:

- Animating or inspiring attention and commitment
- Presenting information or demonstrating process
- Raising relevant questions, developing habits of self-questioning
- Clarifying difficulties or obscurities
- Drawing parallels or finding relationships
- Reflecting feelings
- Expressing agreement and support
- Evaluating, or developing the learner's capacity for self-evaluation

It is essential to understand these roles and how they intertwine in the teaching process (Kidd, 1973, p. 293).

To use the workplace as a resource for learning, adults must acknowledge the contextual complexity of work settings, and problem setting as elements in the process of critical thinking (Brookfield, 1987). Reflective practice to increase self-examination, to assess practice and to promote personal theory building has been endorsed by educators such as Wellington (1991), Sagor (1991), Evans (1991), Killion and Todnem (1991), and Canning (1991).

### The Question of Sufficient Justification

#### Historical Perspective

DeBoer's (1991) A History of Ideas in Science Education, illustrates today's situation with historical perspective. Current innovations are reflective of recommendations for science instruction that span over a century. In 1900, the University of the State of New York reported that the laboratory method was almost universally approved, however, the text-book method prevailed in schools. Laboratory work was reported to be "incidental, inefficient, and in many cases excluded altogether."(DeBoer, 1991, p. 56)

In 1920, the National Education Association Physics Group reported:

The teaching of the past has too frequently assumed that a principle may be readily grasped if only it be once stated in clear language and illustrated by a few examples, and that it may then be generally applied with comprehension and completeness. It is now recognized that principles may be best

arrived at and comprehended through solving problems. From such experiences the teacher should guide and stimulate the pupils to recognize that they must arrive at the generalizations by their own mental processes. (Deboer, 1991, p. 75)

During the next thirty years discussions in science education centered on relating instruction to real-world experience of students. This was an effort to interest students, with the hope that enrollments in science and understanding of science would increase.

Reports in the 1930's indicate that school administrators felt teachers spent too much time lecturing, not enough time on laboratory activities, girls were not interested in the physical sciences, and chemistry and physics had the reputation of being difficult courses. High school teachers were being asked to teach by inductive methods when nearly all college teachers and text books used deductive methods (Deboer, 1991, p. 119).

Inquiry-based science curricula were prominent in the programs developed in the 1960's and 1970's. Meta-analysis found such programs effective in improving student performance on cognitive measures and raising attitudes about science (Shymansky, Hedges & Woodworth, 1990). The importance of teacher in-service was stressed as 33% of teachers in this study had no training prior or during implementation of the new model of instruction.

### The Education of Teachers

Reforms in science education continue to require teachers to teach content in ways they have never seen or experienced (Cohen & Ball, 1990; Novak & Ridley, 1988; Novak, 1987; Huling & Hall, 1982). This suggests that teacher preparation, if it is to open possibilities and promote greater responsiveness to the challenges of teaching; cannot simply suggest new method. Pre-service teachers must have experience as learners with these methods (Anderson & Smith, 1986; Novak & Ridley, 1988). According to Feiman-Nemser & Melnick (1992) "people tend to hang on to familiar ways of thinking, ignoring conflicting ideas or reinterpreting them to fit their current views. Prospective teachers are no exception ... studies show that conventional teacher education changes few beliefs" (p. 5).

Change in secondary science instruction has been promoted for over a century. A change in university science instruction may be an essential requirement to alter secondary instruction.

Wilson and Ball (1991) conducted a study examining what teachers were taught and what they learned, combining case studies of programs with longitudinal studies of participants' learning. The aim of the program was to help develop teachers abilities to involve students in a problem-solving, active-learning approach to learning mathematical concepts. The study followed groups of prospective mathematics teachers over time, tracking whether and how their ideas and ways of thinking, skills, and dispositions changed while

participating in teacher education programs. The program vision was to have teachers "give up responsibility for getting the students to the answer" (Wilson & Ball, 1991, p. 4).

Wilson & Ball found that teachers are inclined to tell and show students how to do mathematics instead of creating activities that help students to construct understanding of the content. The case studies demonstrated that teachers exhibited considerable variation in practice after the program. However, significant and specific changes in mathematics teaching tended to occur only when teachers themselves became active constructivists as learners (Wilson & Ball, 1991, p. 34).

Traditional training and workshops for teachers have had modest impact on classroom practice. Odom (1974) found a negative correlation between change in teaching strategies and length of teaching experience after teacher participation in the Institute for Physics at University of Northern Colorado. Teachers with little or no physics teaching experience more readily adopted the methods promoted by this summer workshop on physics teaching. Teachers with extensive classroom experience tend to be more resistant to altering practice and implementing new models of instruction.

#### Graduate Teaching Assistants

In Ivey's (1992) study of student learning in an innovative science laboratory, it was found that the role of the teaching assistant

is critical (p. 151). Teaching assistant attitude toward the laboratory instruction method and style of interaction with students were reported as important student concerns. Graduate Teaching Assistants instructional beliefs and actions influence undergraduate students (Ivey, 1992).

The intent of science course reform for pre-service science teachers is to develop confidence in their abilities as constructivist learners, to improve their enjoyment of science classes and to motivate for continued study of science.

### The Evolution of Perspective

#### The Researcher's Experience and Beliefs

During twenty years of science teaching, primarily chemistry, personal teaching style and beliefs about teaching have evolved. Early teaching years were dominated by "chalk and talk" - or lecture with blackboard for visual aide. The practice was judged competent by a variety of supervisors and students tested well. Students, however, did not appear to have much "carry over" which was a personal expression for frustration with students' ability to use course content in new contexts.

A sequence of summer study at National Science Foundation Institutes allowed the acquisition of a Master of Science for Teachers degree, improvement of content knowledge, and experience with

"master teachers" in a university chemistry department. A teaching style developed that reflected the models of instruction provided by these chemistry professors. As a relatively inexperienced teacher, instructional methods used by university chemistry faculty were readily incorporated into existing repertoire of classroom practice.

Additional experiences with Institute for Chemical Education (ICE) Programs, Dreyfus Woodrow Wilson Institutes for chemistry teachers, National Science Foundation Seminars, and New England Association for Chemistry Teachers influenced practice. Continued dissatisfaction with the level of student learning and understanding from lecture alone, or lecture with demonstration, led to adoption of practices to improve student engagement in the instructional process.

Schlecty (1992, p. 26) comments "if they (students) don't engage in the work that you've got, then there's no danger of their learning anything." Methods were adopted to provoke students to engage. Since lecture was a passive experience for students and attention waned quickly, strategies were adopted that involved students more actively. The goal was to promote increased involvement of students in their own learning.

Experience supervising undergraduate education students serving paraprofessional assignments and first year teachers, confirmed beliefs that student experiences are important in determining classroom practice. This belief established interest in having pre-service teachers experience various models of instruction in undergraduate content classes.

The Connecticut Beginning Educator Support Teacher (BEST) Program and Connecticut Teacher Assessor Training provided over eighty-hours of training in classroom observations and analysis. After scripting video-taped lessons and analyzing lessons according to the Connecticut Teacher Competency Instrument, the researcher was qualified as a Connecticut State Teacher Assessor. This training, plus over two-hundred hours of class scripting, provided the researcher experience and confidence in recording classroom observations.

#### The Systemic Teacher Excellence Preparation Project

The Systemic Teacher Excellence Preparation (STEP) collaborative project was designed (1) to bring about large-scale improvement in the preparation of mathematics and science teachers in Montana, and (2) to serve as a national model for rural areas with significant minority populations. In order to accomplish these goals, the STEP Project developed new alliances that form a statewide, interactive network consisting of schools (K-12), Tribal Colleges, State Universities and Colleges (with teacher training programs in mathematics and science), the statewide Systemic Initiative for Mathematics and Science Project (SIMMS), which was developing and integrated mathematics program for the state for grades 9-12, the Six through Eight Mathematics (STEM) Project which was developing a complete mathematics curriculum, for national distribution for

grades 6-8, the Alliance of States Supporting Indians in Science and Technology (ASSIST) which was involving Native American students in science and technology projects through K-12 schools and Tribal Colleges, the State Office of Public Instruction, the Montana Council of Teachers of Mathematics (MCTM), the Montana Science Teachers Association (MSTA), and the Montana University System. The STEP Project was supported by leaders from all segments of the Montana population.

One portion of the STEP Project was a team approach to redesign over fifty university mathematics, science and methods courses for pre-service teachers in Montana. Curricula changes were planned that would: (1) show the uniqueness of various areas of mathematics and science, but which also illustrates relationships between interdisciplinary areas; (2) include ample opportunities to work with manipulables and hands-on materials; (3) use active engagement of students in inquiry, problem solving, and model building; (4) provide regular opportunities for social interaction and group work; (5) include strategies to determine and build upon students' preexisting ideas; (6) present real world applications of mathematics and science; (7) include appropriate uses of technology, including graphing calculators, individual computers and computer networks, laboratory interact systems, and video technology; (8) incorporate assessment techniques that involve higher-order thinking skills, problem solving and, when relevant, use of manipulables or hands on materials; (9) use a variety of strategies

for teaching mathematics and science including inquiry-based instruction, cooperative learning, questioning techniques, discussion and presentation strategies, classroom organization and management, motivation, and assessment techniques; and (10) use strategies found to be effective in engaging female and minority students, especially Native Americans, in mathematics and science coursework.

This research project was conceived within the STEP Project strand involved with the redesign of university science courses.

### Definition of Terms

**Misconception** - an idea for which student interpretation is in conflict with the formal concept as understood by formal physics. Other typically used phrases are "alternative conception," "alternative framework," and "naive beliefs."

**Physics 205** - an algebra-based introductory physics class on equilibrium, motion, the forces which cause motion, momentum, the concepts of work and energy, thermodynamics and kinetic theory, fluids and waves.

**Scripting** - a method of recording classroom observations. The Script becomes a record of classroom activity and provides concrete examples for the analysis phase. Acceptable analysis, according to the Connecticut Teacher Assessment program, requires every conclusion be referenced with the statement "as evidenced by" followed

with specific citation or citations from the observation script providing a 'preponderance' of evidence.

Teacher Assistant Training Sessions - weekly meetings for all instructional staff for Physics 205. Graduate teaching assistants work through the student tutorial with the professor modeling the "role" of tutorial instructor. Instructional objectives are clarified and an answer key for staff tutorial use is generated.

Tutorial - a student exercise designed by the Physics Education Group at the University of Washington called the Physics by Inquiry Model. Students work in a collaborative setting with peers to solve problems designed to create "disequilibrium" by confronting common student misconceptions. A sample Tutorial from Physics 205 is provided in Appendix B.

Tutorial Instructor - physics graduate students with Graduate Teaching Assistantships assigned to Physics 205.

## CHAPTER 2

## METHODS AND PROCEDURES

Introduction

The research plan was a qualitative design, since the objective was to document an implementation process and determine participants level of modeling of an instructional method. The investigation determined participant attitudes and beliefs about the instructional role required and about inquiry-based learning.

If the goal of educational research is significant improvement in the daily functioning of educational programs, then Shulman suggests that there is "little evidence that researchers have made discernible strides in that direction" (1970, p. 371). He recommends that researchers step back and regain perspective and identify routes toward development of an empirically based discipline for educational research. Shulman (1970, p. 383) advocates that research in education move away from the traditional laboratory setting view of experimental treatments in terms of single variables, since examination of "educational problems reveals that such approaches are extremely short on educationally relevant external validity" (Shulman, 1970, p. 389). Researchers must not ignore the teacher, but rather researchers must include teachers' educationally significant characteristics as factors:

Research in education will have to venture forth from the safe and sterile surrounding of the traditional laboratory and address itself to that most threatening of settings for the education researcher, the classroom or its carefully created equivalent. Instead of viewing experimental treatments in terms of single variables, such as "phonetic" versus "whole-word" or "discovery" versus "rote," researchers must begin to contrast total educational approaches. e.g., curricula or their parts, whose components have been carefully selected and combined. (Shulman, 1970, p. 383)

Inductive researchers hope to find a theory that explains their data, theory described by Glaser and Strauss (1967) as 'grounded theory.' Purely inductive research begins with collection of data such as empirical observations and builds theoretical categories and propositions from relationships discovered among the data (Glaser & Strauss, 1967; Goetz & LeCompte, 1984).

Goetz & LeCompte (1984) describe ethnography as a process for the study of human life. A process that requires investigation that incorporates three investigative strategies. First, strategies used "represent the world view of the participants being investigated, and participant constructs are used to structure the research" (1984, p. 3), this is phenomenological data. Second, strategies are empirical and naturalistic; direct observations are made of participants in real-world settings. The investigator avoids deliberate manipulation of variables in the study. Third, ethnographic research is holistic. The goal is to construct descriptions of phenomena that "generate ... the complex interrelationships of causes and consequences that affect human behavior toward, and belief about, the phenomena" (Goetz & LeCompte, 1984, p. 3).

The purpose of educational ethnography, according to Goetz & LeCompte (1984, p. 17), is to provide rich, descriptive data about the contexts, activities, and beliefs of participants in educational settings. They recommend participant observation as the preferred data collection strategy, supported with a variety of techniques that create a data base primarily of field notes (Goetz & LeCompte, 1984; Bogdan & Biklen, 1992).

Qualitative research is focused on the interpretive description and explanation of the life ways, and social structure of the group under investigation. The roots of this method lie in anthropology and sociology. According to Pelto and Pelto (1978), the essence of the research methodology lies in seeking answers to the following question: How can we find "true and useful information" about a particular domain of phenomena in our universe? This fundamental question is broken into two closely related problems (Pelto and Pelto, 1978): (1) How can we personally investigate some domain of phenomena in order to obtain true and useful information? (2) How can we know, with some assurance, what other persons (researchers) mean when they assert propositions about information, and how can we judge whether to believe them? (p. 1)

The first question is directed toward techniques for exploration. To study human behavior, the primary data used by anthropologists comes from three sources: (1) direct observation, (2) listening and noting the contents of human speech, and (3) examining the products of human behavior available (Pelto & Pelto, 1978). The

second question requires, that in addition to basic observation, the researcher must follow a set of procedural rules for transforming evidence into generalizations about phenomena.

Once the structure of the data gathering is determined, the systematic review of descriptions is intended for identification of patterns and categories. Controlled and constant comparisons are made, which lead to theory building. Thus, Pelto and Pelto (1978) suggest that the logic used in anthropological data-gathering operations is essentially the same as in all scientific endeavors. The task of the anthropologist is to "reduce to a minimum the distortions of an *uneven mirror* by a careful definition of concepts and specification of research operations, so that the powers and vagaries of the human mind work to our advantage." (Pelto & Pelto, 1978, p. 37)

#### Sequence of Events Before and During the Study

The Physics 205 course was a large algebra-based introductory Physics class at Montana State University. Enrollment included students from the secondary science education major, as well as architecture, biological science, pre medicine, engineering and other students.

The professor began teaching this course in 1992-93, using the predecessor's text and class configurations. During that first instructional year, Physics Tutorials from University of Washington

were piloted in two laboratory sessions. The professor had spent three years at the University of Washington. Part of his time was engaged in the development of instructional tutorial materials with the Physics Education Group.

The professor had committed beliefs on the benefits of the inquiry approach. He convincingly spoke of his conversion from a belief that lecture alone is sufficient for instruction to an adoption of lecture plus the Physics Inquiry Model of Tutorials. Affiliation with the STEP Project allowed Physics 205 to gain endorsement for reform and some financial support for this implementation effort.

The Physics Department traditionally provided Physics 205 Graduate Teaching Assistants as Laboratory Instructors. A plan was developed to use these Graduate Teaching Assistants as Tutorial Instructors. The Physics Graduate Teaching Assistants for Physics 205 were assigned by the Physics Department from the available Physics Graduate students. No special selection process for Physics 205 teaching assistants was used.

The professor reported that additional instructional support for implementation of tutorials in Physics 205 was provided by STEP teaching assistants and undergraduate work study teaching assistants. These teaching assistants for the tutorials were chosen, not only, for knowledge of physics, but also, for their "people skills."

The Fall 1993 enrollment for Physics 205 was 338 students, configured in two lecture classes and 18 laboratory-tutorial sections. Tutorial sessions attempted a 7:1 student to staff ratio. The physics

graduate teaching assistants served as the lead teacher for each tutorial section. The graduate teaching assistants were assisted by undergraduate university work study students and STEP assistants to achieve the desired 7: 1 student to instructor ratio. Teacher support from the STEP project included a local high school physics teacher and this research assistant. Each Tutorial section, about twenty students, had three instructors: a physics graduate teaching assistant plus two assistants.

Teacher assistant training sessions were scheduled on Monday afternoons prior to the first student tutorial class. Training sessions mimic the student tutorial process. Teaching assistants took the student pre-test and reviewed sample student pre-test responses. Teaching assistants worked in groups of three or four on the tutorial. Each group worked for a common solution via discussion and diagrams sketched on a common large sheet of news block paper. Once consensus was reached, individual answers were recorded on tutorial sheets. The tutorial sheets, completed in the training session, were a guide for each staff member to use in verification of student responses.

Students left tutorial sessions with a self completed answer sheet for the tutorial. The objective was to generate extensive explanations written "in students' own words" that had been arrived at by team effort and validated by the instructor. These completed tutorial papers were then available for student reference when doing a post-tutorial homework assignment. The homework assignment

was turned in at the next session and graded by the teaching assistant.

Points were given for attendance and graded homework, but students were responsible for completion of a comprehensible tutorial sheet that served as their personal study guide. Tutorial sheets were done by the student, for the student and were not graded.

During teaching assistant training sessions, the physics professor modeled the role of the Tutorial Instructor. He presented questions to guide thinking, determined if groups had arrived at appropriate conclusions, encouraged the group process, kept discussion at the conceptual level of the students, and guarded against use of terms not yet defined to students in Physics 205. Jargon was avoided and the frequent explanations requested were written in complete sentences using normal student language.

Instructional objectives were clarified, so that each Graduate Teaching Assistant, work-study undergraduate and STEP staff assistant understood, in specific detail, what undergraduates were expected to experience and gain from the tutorial. Tutorial training sessions allowed staff to experience, first hand, the dilemma or quandary that students confronted in each tutorial. Staff reached consensus through discussion and debate, using the same process that students experienced in tutorial sessions.

Graduate Teaching Assistants were lead instructors for two or four tutorial sessions each week (specific graduate teacher

assignments varied). Graduate Teaching Assistants corrected tutorial homework assignments, staffed the Physics Learning Center, graded common hour exams and provided office hours for individualized student extra-help sessions. Hour exams were scored the evening of the exam. Student exams were returned during the next lecture class following the evening exam.

### The Setting

The two lecture sections met in Room 108, Reid Hall. Students were seated in individual wooden student desks, with a fixed tablet arm. Desks were arranged auditorium style, in several tiers on a cement and tile floor. This large lecture hall had a demonstration counter on a raised wooden area at the front of the hall. An overhead projector on a large trolley, a screen mounted high to the front left of the room, blackboard space on a series of movable panels and a projection system in the back of the hall were the instructional aids available. Two doors entered from the corridor: one at the front of the room facing the demonstration table and one at the back, with several steps, leading to the top tier of the student desk area. A large number of 'mail box' style slots were in an alcove leading to a third door connected to the exterior of the building.

Lecture section #1 met Monday, Wednesday and Friday at 11:00 a. m., followed directly by section #2 at 12:00 p.m. Four common hour examinations were scheduled evenings, at 6:00 p. m.,

in the Leon Johnson building in a lecture hall accommodating all students from both lecture sections.

The eighteen Tutorial/Laboratory sections were held in Room 127 of the A. J. M. Johnson Hall. This had been the traditional meeting room for Physics 205 Laboratories. Furniture consisted of two room length fixed tables surrounded by stools. The room had black board space across the front, windows on the west side, counters mounted on three sides of the wall, and miscellaneous equipment mounted on the south wall.

Tutorial Teacher Assistant training sessions met, in this same room, Monday afternoons at 4:00 p. m. The student tutorial schedule began Tuesday, 8:00 a. m. The eighteen two-hour sections occupied the room for 36 hours each week. The last scheduled weekly tutorial session ended Friday at 2:00 p. m.

#### Role of the Researcher

As a Research Assistant with the STEP Project, the professor gave permission to attend class meetings and supported the research effort to document the implementation of the Physics Inquiry Model for Physics 205. In addition, the researcher was a teaching assistant in Laboratory Section #16, and attended all Tutorial Training Sessions.

As a tutorial instructor the investigator taught the physics inquiry method with the graduate teaching assistants. Participant

research in classrooms has precedents such as Ball (1992, 1993) and Wolcott (1987) whose studies were constructed with investigations done in their own classrooms.

The physics Graduate Teaching Assistants understood that research was being done to record the process of implementation. They were introduced to the researcher at the initial Physics 205 staff meeting on August 24, 1993. The researcher was given verbal permission to attend tutorial class meetings by each of the Graduate Teaching Assistants and made an effort to remain as unobtrusive as possible, when making field notes during tutorial sessions.

Informal graduate teaching assistant discussions about tutorial sessions during the first and second tutorial training sessions provided insights leading to the conception of this research project.

### Data Collection Methods

The following methods of data collection were used: (1) a participant observation journal was kept to record impressions of teaching assistant training sessions. The journal recorded common instructions provided to all teacher assistants. Reflections on conversation and comments by teaching assistants about tutorial experiences were recorded in the journal as informal interviews; (2) field observations for five tutorial sessions were done for each of the physics graduate teaching assistants, including two audio taped and one videotaped tutorial; (3) two formal interviews with each of the

teaching assistants were done to determine individual perceptions and opinions during the middle of fall semester, 1993, and early spring semester, 1994); (4) to acquire an overall picture of the course, lectures were attended and homework assignments and test materials were reviewed; and (5) a document file was kept for instructional material related to Physics 205.

Appendix C provides the Research Time Line and Appendix D contains the Data Collection Schedule.

Multiple methods of data collection were used to provide the triangulation or cross reference of data desired in naturalistic studies to create a diverse source for and reinforcement of researcher observations (Goetz & LeCompte, 1984).

#### Participant Observer Journal

Spradley (1980) recommends a fieldwork journal, like a diary, to contain a "record of experiences, ideas, fears, mistakes, confusion, breakthroughs, and problems that arise from fieldwork. A journal represents the personal side of fieldwork: it includes reactions to informants and feelings you sense from others" (p. 71). The introspective record assisted in identification of personal biases and feelings, which needed to be understood and evaluated as influences on the research. Review of the journal assisted in reconstruction of events during the early weeks of the study. Spradley (1980)

indicates review of the journal tends to reveal how quickly details are forgotten.

The journal was used to record specific information about Teaching Assistant Training Sessions, impressions from informal interviews with graduate teaching assistants and the professor, details about the evolution of the study, and thoughts after making field notes in tutorial sessions and lectures.

### Fieldnotes

Descriptive observations, called scripting, were made during five tutorial sessions for each graduate teaching assistant using methods described by Bogdan & Biklen (1992), Goetz & LeCompte (1984), and Pelto & Pelto (1978). Appendix C and Appendix D provide a summary of procedures, time line for data collection, and data collection schedule. Initial observations established rapport, allowed students and instructors the opportunity to become comfortable with the researcher's presence, and provided an opportunity to gather general information and to make overview notes.

Observations increased in focus as the study progressed. Codes were established to record information in a manner which supported the sorting of categories for data analysis. During the data collection phase, review of data was in a continuous process of constant comparison to provide the researcher the opportunity to recognize

patterns to explore in future sessions. Bogdan and Biklen (1992) suggest that the researcher forces decisions that narrow the study (p. 154), develop analytic questions during the study (p. 155), plan data-collection sessions in light of what is found in previous observation (p. 157), write observer's comments about ideas generated (p. 157), investigate ideas and themes on subjects (p. 159), consider metaphors, analogies and concerns to avoid "nearsightedness" during data collection (p. 162) and develop visual code devices to use in analysis (p. 163).

Tutorial sessions were characterized by considerable conversation. Scripting of instructor-student dialogue was limited to groups seated closest to the researcher. Observations noted much of the tutorial activity, but audio tape recordings were done to provide tutorial instructor comments and dialogue with different student groups. Teaching Assistants wore an inconspicuous wireless-microphone during the taping. Pre-study taping was done to accustom students and instructors to the equipment and to test for possible technical difficulties with taping.

One tutorial videotape recording was made for each of the physics graduate teaching assistants. A schedule for observations and taping is found in Appendix D.

### Formal Interviews

Each graduate teaching assistant participated in two formal interviews. The dates for each interview appear in the Data Collection Schedule, Appendix D. The interview format and questions were carefully formulated using structures recommended by Spradley (1979), Patton (1980) and Seidman (1991).

It was essential to establish rapport with each informant, maintain a neutral stance, respect the informant, encourage informant to articulate beliefs and avoid leading questions. The style of the interview was egalitarian, between the interviewer and the informant. The informational interviews were designed to draw out the participant without creating a researcher-subject atmosphere (Patton, 1980). The interview format and questions are provided in Appendix E.

The interview format and questions were designed to focus on issues of concern to the study. The interview captured the informant's view of the tutorial process and defined the instructional role from the graduate student's perspective.

The first formal interviews with each graduate teaching assistant were scheduled during the middle of the fall semester. The second formal interviews were scheduled during the early part of spring semester. Formal interviews were audio tape recorded and transcribed for data analysis.

Prior to the second interview, Graduate Teaching assistants were provided a transcript from the first interview for review. Miles and Huberman (1984) suggest that feedback from informants is a logical source of corroboration.

Feeding findings back to informants is a venerated but not always executed practice in qualitative research. It dates back at least to Malinowski's fieldwork in the 1920's, and has been used in numerous field studies since then. ... classified feedback to informants as a source of "phenomenological validity," and Guba built it into his repertoire of devices for assuring the "confirmability" of findings, using the sociologists' term "member checks." (Miles & Huberman, 1984, p. 242)

The second formal interview provided time to reflect and discuss teaching assistants' responses from the first formal interview. The second interview offered the opportunity to elaborate, revise and clarify previous interview responses.

### Document File

The course syllabus and samples of all tutorial pretests, tutorial sheets and tutorial homework assignments were collected and reviewed. Appendix B contains a sample Tutorial and a sample Tutorial Pretest.

### Data Analysis

A process of constant comparison of data was done during and after data collection. The constant comparative method first

developed by Glaser and Strauss (1967), and amplified by Glaser (1978), was used to analyze the data. This method involves identifying initial patterns or issues in the data which relate to the research purposes; collecting additional data in order to discover new facets of previously identified categories; adding or deleting categories as warranted by incoming data; describing and interpreting both category-validating incidents and discrepant ones; and continuing to sample and categorize data until a core group of data-supported categories, patterns, assertions, or hypotheses emerge.

The constant comparison method was used to determine how interview information, regarding informants convictions and beliefs, compare with tutorial observations. Some studies have shown that inexperienced teacher behaviors are not consistent with their self-reported belief system (Brickhouse & Bodner, 1992).

Categories of instructional statements from observations were developed from an analysis of fieldnotes, the audio taped recordings, videotape recordings and tutorial scripts. Categories of teaching assistant instructional comments were created to determine how often graduate teaching assistants used instructional questioning appropriate to the tutorial goals as established in tutorial training sessions.

Frequency of instructional statements by graduate teaching assistants were clustered in the following categories: (1) probing questions to focus attention, (2) leading questions with one obvious

answer, (3) direct instruction - explains concept/procedure, (4) gives feedback, (5) checks knowledge, (6) management of group process, and (7) other. This methodology is similar to an educational study done by Fogarty, Wang and Creek (1983) concerned with teacher actions and teacher decision making.

### Limits of the Study

This study described the graduate teaching assistants' perspective of their role in the implementation of Tutorial Instruction in Physics 205. To facilitate training for the instructional role of graduate students, it was necessary to determine what beliefs and concerns were held by graduate students.

The study described the pattern of interaction between the graduate research assistants and the Physics 205 students in tutorials. This was done to determine if instructional objectives for the tutorials were supported by the actions of the graduate teaching assistants.

This information may not provide information valid for other instructional methods, different training sessions, or graduate students with personal characteristics that are radically different from those studied.

The following limitations restrict the generalizability of the results of this study:

1. The study was completed by a single researcher in the department of physics at one university during one school year. The investigator acknowledges that it is not possible to be completely objective and free of bias. Global generalizations to other universities or departments are not possible.

2. The participants were Graduate Teaching Assistants for Physics 205, assigned by the Physics Department. The typical department method for assigning graduate student teaching assistants was used. No additional selection process was done by the investigator. Global generalizations to other teaching assistants are not possible.

3. The study investigated five teaching assistants during seven months, thus, insights into the teaching assistants' role in the implementation of inquiry-based learning in Physics 205 represented a limited view of teaching assistants in large university introductory science courses.

#### Significance of the Study

Goetz and LeCompte (1984, p. 59) indicate that research has begun to engage in studies beyond descriptive analysis. Such studies require a wider range of techniques to ensure reliability and validity of the research results.

Acculturation, socialization, and schooling are abstract constructs most readily operationalized in natural, ongoing behavioral transactions and are most directly accessible

through observation. However, as their concern for the enhancement of construct validity - the extent to which abstractions are meaningful and shared across times, settings, and populations - increases, ethnographers have become more concerned with supporting constructs through multiple data-collection strategies. (Goetz & LeCompte, 1984, p. 59)

This study used a variety of data-collection strategies to enrich and broaden the data base. Information from participant observation, informal and formal interviews, videotapes and audio tapes were analyzed by constant comparison to conceptualize and substantiate research findings using methodology from Goetz & LeCompte (1984, pp. 179-192).

Data was collected in natural settings rather than in a "contrived or laboratory" setting which Goetz & LeCompte believe results in validity as a major strength of ethnographic work, while reliability poses the greatest threat (1984, p. 221). Qualitative analysis requires a process of researcher self-monitoring, that exposes all phases of the research activity to continual questioning and reevaluation.

Credibility requires that data analysis techniques be "traced and justified so that readers of the study may examine the inferences, comparisons, generalizations, predictions, or metaphors that contribute to the study findings" (Goetz & LeCompte, 1984, p. 241). Presentation must convince the reader that the study adequately presents the reality of the investigation by providing "sufficiently dense, complete, and representative data" (Goetz & LeCompte, 1984, p. 242).

This study was interested in a group of people involved in a process to bring inquiry-learning to a university course. It created a picture of the role of the graduate teaching assistants in Physics 205 by providing detailed descriptions and analysis of their instructional actions, as well as insights into their beliefs. The success of efforts to improve teaching in classrooms hinges, in a large part, on understanding of the forces that shape, and either directly or indirectly constrain, teaching practice.

## CHAPTER 3

## ANALYSIS OF DATA

Introduction

To create an accurate depiction of physics graduate teaching assistants as tutorial instructors, a profile has been done for each physics graduate teaching assistant in Physics 205, Fall 1993. Names used were pseudonyms drawn from individual teaching assistant's linguistic and ethnic backgrounds. Pseudonyms accurately reflect the teaching assistants' gender.

Following the teaching assistant profiles, this chapter also contains four sections which were aligned to the four purposes of the study and the research questions summarized in Appendix A. The research questions were answered using details from the data to provide evidence. The four sections which follow the profiles:

- (1) Graduate Teaching Assistants' Model Physics by Inquiry Method;
- (2) Graduate Teaching Assistants' Perspective of the Tutorial Instruction Process;
- (3) Graduate Teaching Assistants' Opinions on Training Methods for Tutorial Instruction;
- (4) The Role of the Graduate Teaching Assistant as Instructional Support Staff in Large Introductory Science Classes.

### Graduate Teaching Assistant Profiles

A profile for each physics graduate teaching assistant has been created as background for understanding their perspectives and beliefs about how they and their students learn science. Interview data and observations were used to portray each teaching assistant as a unique individual and to aid in the comprehension of their teaching style.

#### Tom

Tom was a first year physics graduate student at Montana State University. He graduated the previous spring from a large midwestern university and selected MSU for graduate work since "they gave me money - the other school, Texas didn't, and they're strong on surface science - my interest."

First impressions of Tom were that this young man had an intense and serious nature. Perhaps it was his first year status, but he did not engage in the usual teaching assistant repartee prior to group meetings. These exchanges had a teasing quality regarding intellect and physics ability or made gallows humor about graduate student life in general: working late nights, no sleep, no social life, no money. The two foreign teaching assistants and Tom remained aloof during these exchanges. For the last months of this study, Tom

stopped shaving his heavy dark beard. This gave him a scruffy look for some weeks, but resulted in a thick beard. The beard, flannel shirt-jeans attire, plus a burly stature, gave Tom a rough, kind of mountain man image.

About mid-semester, Tom appeared tense and pale. When asked if he felt okay, he reacted defensively stating he hadn't slept, was doing too much and had a lot of work to do. The pressure and intensity for a first year physics student became apparent as Tom described working routinely to midnight or two a.m. at the university (all night on some occasions), doing problem sets in preparation for June comprehensive exams:

as long as I pass (comprehensive exams) at the Ph.D. level then I automatically get into that program - if passed at masters level then that's it - but you get two chances to pass - or you're out. These courses are basic, but also designed for the comprehensive -first year people are strung out (laughs) that's the reason.

While Tom talked openly about personal stress and twice during the semester suffered bad colds, he was never observed being sharp with students and he went out of his way to be helpful - "If you can't make help center, come to my office" and "if you get stuck see me." Tom often made reference to his own student status - "Take the advice of a fellow student ... it's important to be ready for exams."

Tom's conscientious and efficient nature showed in the care he took with record keeping chores such as attendance and grades, prompt return of student papers, questioning students about missed assignments, rescheduling tutorials to assist students and

encouraging students to get extra help when needed. Tom described tutorials:

It is more of an interactive thing than the traditional physics course, ... we're ... going around and helping the individual groups of students. ...lead them down the right path rather than just dumping answers on them. I don't think they learn that way, but if someone points them in the right direction - I think they learn that's more of our job than anything else. Pointing the students in the right direction and get them going and thinking in the right direction and let them learn.

Tom described his experience with science instruction as "exclusively the traditional lecture type of thing - nothing different" and he found the tutorial system "promising," "pretty exciting," "a revolutionary way of doing things."

I'd never - you know - run into that before in my own education - I'd never heard of it before, so it was exciting to me.

I think overall it's been a positive experience. Certainly I've learned, my own self - my own knowledge of physics has become much better through teaching it this way and my suspicion is that I've gotten more out of it in that respect than I would perhaps in traditional type of environment and I think we're probably doing better at getting the point across too - to the students - than in the traditional way. So, I'm still excited about it.

Tom's perception of the greatest weakness in tutorials: "the single largest thing hindering the tutorial process is lack of preparation by the students." He believed this included both academic course prerequisites and general background with "abstract thought." He also spoke about student "attitude." Tom found that students expect a lot even if they don't give much and that many

students are in the class "just cause they have to be" without any real interest. Tom talked at length about student groups, however, even with repeated prompting, he did not mention group management as a difficulty or problem.

Tom found grading homework a disappointing experience:

some of my students - I know them well enough - I know them by name - they turn in a paper and I see what I thought they learned in tutorial - what I thought they were walking out with ... they had a rough spot in tutorial and I help them through it and their eyes kind of light up and I think - okay they got it now!

And then the homework comes in and they didn't have it. They lost it somewhere along the way. ... the homework is the worst part of it. Because it's ... it's not only paper work, it's drudgery and it's time consuming - but it's frustrating because, I know that in a lot of cases where they got something wrong, all you'd have to do is say 'look here - what you did here' - and give them just a little crumb and they would "oh OH" (laugh) and they'd have it. Once they get out of class they don't have that - they're on their own.

Tom described the strengths of the tutorial process:

If we were doing the traditional course with - 'here's the problem, here's the algebra and we get some number out' - I don't think we get any deep physical intuition from that. The tutorials confront them with their beliefs.

One of the biggest things is the close interaction between the students. You know I've gone into some of the labs here, that are the traditional labs, and they're using apparatus - and I've observed my fellow TA's and there's not as much interaction - and when you have things sort of laid out for you in a lab manual you're following a recipe. Not as much interaction between GTA and students - I don't think you can get more

interactive than tutorials. You can't get more interaction than that!

Two important teachers in Tom's history were:

A high school science teacher:

I had some interesting experiences in High School. With one teacher in particular who kind of let us - well I had Earth Science my freshmen year with him and we did the traditional thing and then later on I had an independent study thing and I went back to him as he was kind of my advisor which was interesting and I got a lot out of it ...

Interviewer: Tell me about that?

Well, if you want to get down to it, he's the reason I'm here. We're still good friends.

Interviewer: He encouraged you to go to graduate school?

My suspicion is I might not have even graduated High School if it wasn't for him. Cause when I ran into him, I was ... well - shall we say a messed up kid (nervous laughter). He really straightened me around. He got me excited. He got me thinking.

Interviewer: You think about him now that you have this teaching job?

Yah, I've been meaning to get around to writing him a letter to tell him about this teaching.

You know I never thought I'd like this teaching this much, but I've been really enjoying it and enjoy doing this.

An undergraduate physics professor:

My advisor who I worked for (work study) ... I had him for one lecture course and he did things differently from anyone else that I remember - in that he would, figuratively, grab students

by the neck and drag them into the lecture with him. You had to be paying attention. He went beyond asking rhetorical questions of the students, but I got more out of that than any other lecture class.

I talked to some other students who had him ... well they changed out of the major because of this professor - they got so discouraged because they were put on the spot that way - well I learned more and it helped that I worked in the lab for him. If something wasn't working right he would ask you questions and you'd end up answering your own question. Well it's almost like the tutorial - you end up answering your own question - so I learned more from him that way.

Some people were really afraid of him - I know other people who liked his teaching style because it was very interactive and not like sitting back and watching TV. When you went to that lecture you had to be thinking and some people didn't like that I guess and ended up by getting out.

While Tom stated he had "only traditional education," a high school independent study in science was advised by a teacher - "friend" who had a profound effect on his teen years. His work study research experience as an undergraduate "turned him on to science." He called this experience "like a tutorial."

Tom's instincts were excellent. He was enthused about teaching and cared deeply about student learning. Tom's efforts as a Teaching Assistant were rewarded in that he was promoted to Tutorial Coordinator for the next semester. He would instruct more tutorial sessions, six to eight each week, but would not be a lead teaching assistant with homework grading responsibilities. He would have a greater role in the design and refinement of tutorials, and

teaching assistant training. This was an appropriate reward for a teaching assistant who enjoyed student interaction.

### Uve

Uve was an East German, beginning work at the Ph.D. level. He left East Germany:

when the wall came down, I went to Mexico because that was the only place I could get a ticket to from East Germany. And when I was in Mexico I had a friend in Los Angeles ... she called me and said she's in Bozeman now. And I had no clue - I looked it up on a map and I asked her what's there? I mean, if I go up there, what's there besides 25 thousand people? And she just told me and I went up here and I offered them (Physics Department) my work - I didn't get paid.

After one year at MSU as a volunteer "learning physics and working on the accelerator," Uve returned to Germany. He completed a masters degree in Germany that required a "practicum - they wanted you to do it in a company factory sort of thing to get your hands on things." Uve returned to MSU and did a four and a half month practicum, in 1992. The analysis done at MSU, on Titanium in the surface science area, was used for his German masters dissertation.

Fall, 1993, Uve was a first year physics doctoral student, he faced exams in June, so his life was "homework and sleep." He routinely worked late into the night with other first year students

It's amazing, you have to work in group. On your own you get lost and try a different way - and to get caught up (makes a struggling face) - so, we always get together.

Uve's English was accented, but easily understood. Previous experiences living in the States and tutoring English in Germany developed his language skills. He was confident and comfortable with English. The one time he was observed in student conversation, when he did not understand the student's expression, he freely joked, saying "don't use strange word, when you talk to me."

He was proud of his heritage, shared pictures and postcards "from home" with the teaching assistants and decorated his study area with German travel posters. However, early educational options were limited by his life in East Germany.

When it came to serving in the army, in East Germany, it's mandatory, I chose to be conscientious objector which the party or the government didn't want me to do that. So, you kind of got a punishment. ... They said you won't be able to study at all at the university, no way.

(even though) they said to me 'there is no way you can study at all.' ... I found this one university, where they didn't care about your background, because they had all those fires, and no one knew what was going on. (but) I could only study math, physics or theology. That's it.

So, Uve studied physics. He described his German education as:

totally different from ... here - everything was different - everything was written on the board for us, for students. So that means, you can cover exactly that amount of material that you can understand. Just because the guy writes everything on the board, and you copy everything from the board, so everything is hand written and ... you get everything. It seems you have time, like if you have transparencies ... there is no way you can finish - (not enough time to) understand.

(lecturer) is talking when he's writing and you can interrupt, ... and they do ... every calculation on the board, every step of the physics on the board. They don't skip, like 4 or 5 steps, so that's really easy. And then, we just had normal labs.

Interviewer prompt regarding style of instruction:

We had lectures and seminars. Since we were only ten students, sometimes eight, or even five. I've had (classes with) only two ... lots of interacting.

At the initial Physics 205 staff meeting, it was apparent that Uve was skeptical about the tutorial system. He seemed to challenge the instructional strategy and requested the research associated with the tutorial process. At the time, a senior work study student described reviewing for MCAT Exams. She eloquently expressed that review of topics learned with pilot tutorials in 1992-93 was far easier, than review of topics learned without tutorials. She testified that, to attain the same level of understanding, she had to do a much greater review, for topics studied without the tutorial process. Her articulate, candid and frank comments as a former tutorial student quelled questioning the process. Uve admitted early skepticism:

I was really suspicious about how (tutorials) could work because, when this started, I thought it was like having this community and everything is fine and everything is just happy (shakes head and makes hand gestures).

I thought it wouldn't work, because I thought ... like physics is true or it's not true, so there is no way you can discuss this.

$2 + 2 = 4$ . There is no way you can discuss that.

I had no clue as to what tutorial was.

After two months work as a tutorial instructor, Uve compared his prior laboratory experience to the tutorial:

in Germany... students ... had no clue what they've been doing, measuring the density, and they just had no clue. They had lab manuals ... and they were just copying all this stuff, and getting ... results ... everyone knows what the lab is like ... even if you do the experiment right (sometimes) you can't get the right result ... and so, it's just ... getting a number at the end ... like the density-you got the right tabulated value for this, but they didn't learn anything by doing this.

The basic difference is that (in tutorials) they don't have to solve for actual numbers at the end ... It's basically, the result is they get something out of it, they learned something ... So I think that's the basic difference.

Uve didn't believe that he could learn physics by "just talking."

I don't know, it seems so silly to interact and those things that they have to do, in the tutorial, in a serious manner. Like this thing is moving around the track and at different speeds and some students have fights about that even (laughs). They argue that hard! (emphatic statement) It's amazing and it's good. I mean, they learn a lot. But I don't know if I would want to do that.

I learn a lot, but I think I wouldn't like it - being the student and arguing about physics and like it. It doesn't make sense at all (laughs).

Even if Uve wouldn't personally choose to be a tutorial student, he felt "this kind of thing would really help (80% of students) to understand. What they do over there (East Germany) would not help them."

Uve believed that the "really smart (students).... know everything - just write everything down without caring what the

others do. ... And (he didn't ) blame them for just going off and doing the stuff." But he saw a strength in the tutorial process for the majority of students:

They understand by having this discussion.

They ask a question and I start to answer it, and I get interrupted, because somebody thinks he can answer the question better.

They learn by teaching the others. Yes that's the best way.

And they learn by arguing and not taking everything for granted.

If I said it, they'd say that's fine ... and forget about it. They would just listen and not think.

Uve admitted that in tutorial he learned physics and how to explain it "because we don't use any math. That's the thing ... making words out of the formal side of science ... is totally different from what I learned." He believed "it's totally different and I like it ... much easier to explain (physics) this way to somebody who doesn't know anything about it."

Uve liked teaching, felt comfortable teaching and wanted to be a teacher, but earlier, in East Germany, "teaching was forbidden" for him. He identified with the students who don't feel passionate about physics:

That's why students feel comfortable with me, I know what they are going through - they don't like it - and I know exactly what they feel.

And I'm not there to convince them how great physics is. I'm just there - I'm trying to help them to get through this course. And that's what most of them want.

Let's face it, they're not in there because they just love physics. And that's the same position I'm in, I'm not in Physics because I love it passionately. I'm there because it's what was available (in Germany).

Uve's graduate teaching assistantship assignment changed for the next semester. While he taught two tutorial sections Fall semester, he was to teach four tutorial sections during Spring semester.

### Ben

Ben was a second year graduate physics student, enrolled in a masters program. He was tall and slim, had an athletic look and was exceptionally personable and affable. He demonstrated a natural friendliness to everyone. Ben often "dropped in" on other teaching assistants' tutorials to say "Hi" to them and visit briefly. He routinely chatted with students about concerts, athletics and happenings about campus.

During the early fall, Ben was often seen socializing before and after tutorials on the lawn outside the physics building. Ben's dog, a Great Pyrennes, was a special favorite, adored by many of the students. They frequently asked about Ben's dog, especially later in winter, when he didn't visit campus as often.

Ben had an easy confidence. During the prior year, he was a Laboratory Instructor in another physics course. He enjoyed the

work and had been a substitute lecturer for that class. He saw a lot of similarity between the role of laboratory instructor and tutorial instructor - with the exception of:

asking questions and the matter of how we're supposed to ask questions to get the students aware.

We're trying to emphasize getting the students to think more and through that inquiry - to get them to say that - instead of us telling them, which is more like labs.

He seemed eager to participate in this study and volunteered for the initial practice audio taped tutorial, making light of the microphone and teasing students that he was wired for a "drug bust." Later, at the end of the semester, he admitted that he did not like wearing the microphone, that it did make him uncomfortable.

Ben routinely introduced each tutorial with a concise overview for students. He described his job as a tutorial instructor as a guide to "keep students on track," to "help the students with problems they might have" and to assist them to "come out of the session with certain ideas in mind." When asked how he does that, he answered:

Well, the tutorial itself is pretty structured with questions that build on each other ... start on a real fundamental level and, through answering these questions, the students are put in situations where they have to use the principles.

Often times they put down their own ideas, as opposed to the correct physics ideas. And I'm there to point out what's wrong or see if I can make them see what's wrong.

Often times the tutorial is set up in a way that the student is asked to put down what they think is correct - and then go

through - based on those assumptions - and turn around and - on the next page say - find out that they contradict themselves ... that sort of thing.

Ben saw his role as a "good opportunity" to work with students and he liked that, although he found that:

A lot of times it's hard to get the students to sit down and work as intensively as we do in tutorials. ... because it's hard to get them working on it (tutorial). I don't think they would (do tutorials) on their own. That would be pretty rare.

Ben was critical of apathetic teaching and preferred instruction with an emphasis on discussion. He liked an "open ended" class structure, where time was provided to talk about a topic and ask questions. He disliked classes with:

a very staunch person who won't entertain questions, except after, in office hours.

They just give information, but they don't want interruptions, it's prohibited.

Interviewer: They actually say they don't take questions?

Well, I don't know if I ever had that happen, but it's just the way you feel in the class. You might ask a question or two, but it's put down pretty quickly (laughs). So, you catch on pretty quickly and the whole class is silent the whole time.

Interviewer: As opposed to other kind of professor (open to questions)?

Yes, and it's an easy feeling.

Interviewer: You feel free to ask questions and are encouraged to do that?

(nods, yes) And the rest of the class is asking good questions and you want to be part of it, so you try to come up with these - you know thinking about what's going on - rather than just passively scribbling off the chalk board.

While Ben had never had instruction like the tutorials, he reflected on what it might have been like:

I think, definitely, back when we were doing this material, we were being exposed to it, it would have been great. We would have learned it a lot better than (pause) than I know now.

Like a lot of this is great review it - it puts a level of understanding, that I never had. I think I've benefited definitely.

Ben saw the greatest strength of the tutorial process as the staff. "It's good to have as many people as we do have and how we're able to work together and keep a consensus on what we're trying to do for each particular tutorial - it's a pretty good idea."

Ben was critical of students who come to class without preparation:

We're required to admit people who are not prepared right now and that is to the detriment of every student in the class.

I think, on the whole university level, I think that's a problem in our college. I don't know if we're going to see an end to that or if it's going to get worse.

It seems like it's getting worse. (laughs) Undergraduates that are not prepared for the next course and the freshmen that come in - not just our class.

It's a campus wide problem.

An additional concern, for Ben, was students coming in with a "bad attitude" or "apathy."

The tutorial is intensive, in that you have to sit down and think ... for a lot of students it's new to them (chuckle). They haven't really had to say very much - and to think about physics, for some people, is the worst possible (laugh) nightmare that they have to get through.

Ben felt homework was important for tutorials in that "it gives them (students) a chance to re-solidify on the ideas they should have taken with them when they left."

Ben summarized what he liked the most about being a tutorial instructor:

Well - I think it would be - the working with the students. I'm a people person I guess. I like to get to know them and work with them, help them along with their problems, what ever they have - see them progressing. It's kind of a satisfactory ... to see the happiness, every now and then (laughs).

Ben was to continue his graduate teaching assistantship as a tutorial instructor for the next semester.

### Suyuan

Suyuan was a Chinese graduate student, in her third year in a physics doctoral program. She lectured physics for two years at a university in China, before coming to MSU. Frequently, other teaching assistants asked questions of Suyuan as her knowledge, understanding and comprehension of physics was extensive. While

she was diminutive in stature, almost childlike in appearance, she was well respected by the people she worked with.

Suyuan was a reluctant participant in this study. She appeared tense and nervous in interviews and stated that she would have preferred not to be audio taped in tutorial.

Communication was somewhat difficult with Suyuan. While it was fairly easy to understand her English, she did not always grasp the meaning of spoken English. Sometimes she misunderstood questions, so her answers were not appropriate. One example from tutorial: a student seeking to schedule extra help on the previous week's homework, was told that she "would accept the homework late, but would points off." The student was hesitant to clarify his request and left the matter unresolved. During the research interviews, it was necessary to repeat and clarify questions. Even then, answers were not always quite representative of the questions.

When asked to describe the type of science instruction that she had experienced as a student, Suyuan responded:

To my experience, I would say I gained the knowledge mainly from the lecture ... I read a lot and I listen to the lecture ... and I think self study is really important. If you want to be a good student - you really want ... to study ... attention to study, yes.

Interviewer: Your experience has been lecture and self study?

Yes, Yes.

Interviewer: You've never been in discussion groups?

Yah, Some, I mean, when I'm at the university (in China) we don't have so many - we don't have TA's actually. The lecturer, himself, the teacher, himself will have office hours for students.

There are so many students, it's kind of impossible to, you know, have lecture with students asking questions. So, I - I think the only discussions might be among the students, like we don't have much discussions (in China).

But I ... read a lot and then do problems and the problems have two parts. One, is like you have to do the calculation and you use the formula - you make some math. And another kind is, like this tutorial, is only based on thinking. And I think this type is - it helps me to understand physics.

Interviewer: You had lectures, but you never had anything like a tutorial?

No. Laboratories, like yours (traditional science laboratory experiences).

Interviewer: You can't remember having any other kind of instruction?

No.

Interviewer: Always large classes?

Yah, large classes.

Interviewer: How many students?

Like - could be 100 students.

Interviewer: Never personalized?

No, No.

Interviewer: How do you prefer to learn science?

I think, for me ... lecture is important and reading, self study, before you go for help, you should try it yourself.

And then, you still may be have some problems, some difficulties, then I think a helping student (teaching assistant) is very important at this point (nervous laughter). I don't like to get help first thing ... before you study yourself.

Interviewer: How do you think people learn science best?

First, I think they should have the want to study - they want to study - they are ready. If they don't want study - then no way to help. And I think that is really important ... you should study hard.

Interviewer: What do you believe are the strengths of the tutorial process?

I would say it is really very good for students to understand. Before you can use some formulas, to use ... you are doing thing - like you are doing physics and sometimes, if you get students who don't understand physics, and still can do that right. (use formulas correctly without understanding physics).

And I think this part, the tutorial, really helps the student to understand the physics.

(need TA's) to help them because some times it's really hard, I think, for physics to get there yourself. May be you need ... really more time if you don't have a helper (teaching assistant).

But ... also ... If the student really wants to study, if they don't have a teaching assistant there, but if they get the correct result finally, they are going to remember it - may be five, times better than (when) they get it from the teaching assistant.

Interviewer: Why do you think that?

Because if you do something all by yourself and - you always try, that way, and you think hard, then I think it is also helpful to the person studying.

But I don't think it's worthwhile. I think it's better to have a helper there (laughs).

Interviewer: What weaknesses do you see in the tutorial process?

Oh, I think this question depends on cases ... depends on different students - some students might benefit more than others.

I think most depends on their level. Some peoples knows better their physics, right, most don't. Also, depends on their motivation.

I would say, a few cases, the students is just ... want to just finish it. I don't think they go through the questions very seriously. They finish in one hour, one half hour and they leave. But a few learn a lot. Some students might not have the motivation they need.

(long pause)

Or may be I didn't make it interesting, it's possible.

(pause)

But I was thinking, if they really want to learn, I'm there to help them. And sometimes they are in a hurry to get out.

Suyuan felt happy when she could "clear up students' misunderstandings" and "help them to think and learn." When students are "not very interested" or "do not really want to learn," she said "well I know I can do nothing about it. I like students who really want to learn. I like those kinds of students." Even if they

found physics hard, Suyuan believed, if students wanted to learn, she could help them to learn the "hard part, I can do that."

When Suyuan was asked to suppose that she was in charge of training tutorial instructors, what would she like to see happen to assist graduate teaching assistants? A tense moment occurred. Suyuan stiffened, became defensive, she asked: "Do you think we need to be trained?" She stated that she is "not trained," the basis for the graduate teaching assistantship was that they "understand physics" and they are "qualified." The word training offended Suyuan.

Discussion shifted to what she learned from being a tutorial instructor. She began talking about how the tutorials challenged the students to think, but emphasized, that while this allowed her to

"brush up the things that I know before" and "it's a good way to need to spend much time on tutorial problems. something about how to guide students - like for guide them." She saw tutorial instructing like is same kind of thing. Tutorial is for me kind of ter."

laboratory instructor for the next semester, she a tutorial teaching assistant.

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David

David was a fourth year doctoral student at MSU. He had finished qualifying exams and classes, and was in the research phase of his program. He appeared serious, with large round-lens glasses, a longish, thin mustache and beard. His uniform was a waist pack and loose comfortable clothes. Although David appeared elusive, he verbalized extensively in the interviews. His interview transcript was twice as long as the average transcript for other teaching assistants. Interviews revealed an interesting history and strong opinions.

David completed a double major in English Composition and Physics at a small liberal arts college, about 1,000 students, near Madison, Wisconsin. He then earned a masters degree in Physics at a large Michigan university, about 40,000 students. David also did research at a large institution in Texas, before he chose MSU for its strong surface science program and smaller size, about 11,000 students.

David's undergraduate classes were small. First year classes had about twenty students, and, after that, David's classes had six or seven students. Junior and senior physics classes were as small as three students with highly personalized instruction. In hindsight, David recognized that he found his undergraduate environment stimulating:

We'd talk about something in a lit class - and the professor makes a side comment to another reference. And instead of just scribbling it down in their notes, people would go out to the library and get that stuff.

I'd be up until two or three in the morning, arguing about it with students - in the peer group. And It was just something we did.

We would literally call up the professor, many times at 10 o'clock Thursday night, saying 'we can't get these couple of problems.' And they'd come in or talk to us over the phone.

And in lit classes and history classes ... you could - any time of day see (professors)- or in the evenings - you'd see them and talk about stuff.

It's just - that's the way is was. It's why we went to school. We liked school.

David described his undergraduate education as "mind to mind transmission - joint venture learning." He talked extensively about how different the norms were at large "land grant institutions." He found "instruction highly mass oriented" and peer groups different. For the large universities he described the student attitude as: "I'm in school because that's just the thing to do ... just tell me the minimum I need to do to get out of it."

David's transition to graduate school in Michigan was difficult. While he prided himself on his humanities and natural science background, when he entered the masters program he found other graduate students had "superior technical knowledge." David found little common ground for relationships. He found other physics

students lacked an interest in film, current events or art. He described feeling additional alienation because:

Everyone ... their fathers and mothers were ... teaching mathematics and chemistry and physics. ... My father was working as a professional photographer and my mother was a homemaker (nervous laughter). So, I didn't fit in at all.

Their skills were far superior to mine, their physics skills and their interests were far more limited than mine. So, we didn't communicate at all. So, the first year was pretty rough.

I was working alone instead of working with a peer group.

The first year was pretty rough, but I've learned to adapt and I looked for something smaller and this (MSU) has worked out really well.

Because David attended a small college, by sophomore year, he was helping in labs and went on to "run labs and problem sessions." He also taught labs as a graduate student in Michigan and had four years experience teaching Martial Arts and Chi Kung, for clubs and employee wellness programs, and gave public observational tours at a planetarium.

David described tutorials as:

pushing people to a crisis point ... In a lot of ways ... it's exactly like ... Zen Buddhism. Except that instead of worrying about being - you're worried about physical laws.

And so we bring people to a place where common sense breaks down and hopefully keep them on that edge long enough, ... that we can help them fall over through to a 'new common sense' structure ... instead of relying on their 'old common sense.'

We do a lot of different things.

First of all ... try to trap people into caring. Because if they don't care, it doesn't matter what you do. And like anything you try, you're going to get some of the people and your not going to get others.

Interviewer: I'm interested that you talked about Zen Buddhism. Can you tell me more about that?

The whole point in Buddhism is to escape the categorical thinking that we use to understand our minds.

And you can't do it by just telling someone this is the way it is. Think this way and then you're okay - the only thing you can do is have someone who knows it already, someone who's already experienced it, and have that person guide you through a crisis point.

What's the sound of one hand clapping? - there is no logical answer for that, it causes a crisis in a person. So the same thing (in tutorial), it's not as profound, we're not learning about being or anything like that, but we are looking at the laws of nature and the same exact thing.

If we can trap them into caring, then they are vested in the problem, because as soon as they care, as soon as they think they understand what's happening, and we show them something else, that brings them to a crisis point.

what your doing is attacking a very deep ... system, within them ... not something they think about. Common sense ... that's why it's so analogous again to Zen Buddhism.

We don't think about how we think - it's not as profound, I guess, the results, but ultimately their common sense ... is just as culture based as ... other cultural traditions.

They haven't done experiments to prove gravity or friction or anything like that - and yet they have this strange mixture of

Aristotelian thinking and Newtonian thinking, because of culture and personal daily experience.

That's so deep inside of them, that it's just like talking religion or politics. As soon as you start pushing the issues the defenses go up and that's what usually happens.

Tutorial teaching experience rekindled David's enthusiasm for teaching. He liked the surprise element, "staying loose" enough to solve tutorial problems using multiple strategies, being open to student ideas, not being the "impartial imparter of knowledge" and having "both sides learn." He found traditional labs "deadening, they just kill curiosity and the excitement and the enthusiasm" by "fill in the blank ... cookbook following, just get it done, get it out of the way kind of stuff."

David believed that education should not be "training for a job, training to get good grades, or anything like that. This is about learning and there are some really interesting things." He was frustrated that students were "already trained to just do the minimum." For those students:

maybe ... better off doing something else, at least for a little while, and then come back, if you want to try it again. I think everyone should have an education and it should be free, should be very cheap, and everyone should have that right, but it's not something that we should be required to do. Not everyone wants to do it.

He would have liked to get rid of the "hoops" like grades, but admitted to being a "really sticky grader." He was troubled that, although students take prerequisites, they don't have the skills needed - "physics uses a logical structure to understand nature.

And that logical structure is algebra." He would like a pretest at the beginning of the semester with basic mathematics skills. "You would have to have those skills to take this class."

David felt that as many as half of the students in tutorial couldn't "be reached," that "another, maybe 40% of the people, learn to play the game and they ... get a decent grade." He found the other 10% were "wonderful to see ... always surprises ... suddenly these people, that you never would have guessed as making it, are leading the groups and taking charge." It was the students who came "back the next lab and you can tell that it's (a concept in physics is) still worrying them. They're still worrying about that issue. That crisis, and they haven't let it go." David said: "Yah, let's go with that, instead of trying to force them down into ... (one) strategy." This was the excitement of tutorial for David.

David was not a tutorial instructor for the next semester. He was assigned to be an instructor for a large undergraduate physics class spring semester, 1994

#### Graduate Teaching Assistants Model *Physics by Inquiry* Method

Physics graduate teaching assistant actions as tutorial instructors were observed and analyzed to determine if the *Physics by Inquiry* method was modeled in Physics 205, fall 1993.

## Analysis of Instructional Statements

Physics graduate teaching assistant statements were reviewed from scripts, audio tape recordings and a videotape recording made in five tutorial observations for each teaching assistant. Teaching assistant statements were assigned to seven categories. Samples of instructional statements provide illustrations for each of the seven categories of instructional statements in Table 1.

**Table 1: Categories & Samples of Instructional Statements**

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| <p>1. Probing questions to focus attention:<br/>         What happens if ...?<br/>         What if they actually collided, how would you ... ?<br/>         When you took the ball and rolled it, what did ...?</p> <p>2. Leading questions with one obvious answer:<br/>         Is velocity (vector) and acceleration (vector) direction the same?<br/>         When you subtract initial from final (vector) what do you get?<br/>         What is in contact with the block?</p> <p>3. Direct instruction - explains concept/procedure:<br/>         Too many forces here, (TA draws free body diagram).<br/>         Here's the left ball tension force. Put it this way (draws force vector).<br/>         It doesn't matter where on the path you draw the free body diagram, it will look like this (makes diagram).</p> <p>4. Gives feedback:<br/>         Great, okay.<br/>         Yes, the answer is normal force.<br/>         Looks good, so you used it here, you're relying on conservation of mechanical energy.</p> <p>5. Checks knowledge:<br/>         What did you find for momentum, initial and final?<br/>         When you add vectors, what do you get?<br/>         What did you decide?</p> <p>6. Management of Group process<br/>         Did everybody disagree to both ... reach consensus?<br/>         Are you staying together on this?</p> <p>7. Other:<br/>         Keep it (homework assignment) and work on it some more.<br/>         Eight homework count doesn't mean skip last tutorial it will be on final.</p> |
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The total number of statements recorded for each teaching assistant, from five tutorial observations, is found in Table 2.

The number of statements for David was smaller, than for other instructors, for three reasons. First, David refused to wear a microphone. Although he agreed to carry the wireless microphone, he put it in his pocket or left it on student tables. The microphone was not positioned to amplify David's statements to the tape recorder. Recordings were marked by static and interference and were not intelligible. Second, David's tutorial posture was as an "observer," attentive, but aloof. He described his actions as:

What I try to do as a tutorial instructor is - I'm, looking across the whole room all the time, and I keep my ears open all the time. So, I'm, trying always to be aware - of where people have technical problems and I go out and help them with that.

But the main thing, I'm ... aware of everyone else.

When he did "go out" to groups he spoke softly, so that statements were not audible to the researcher. Third, David was assisted in tutorials by other instructors who were assertive, directly engaged students and spoke in louder tones.

**Table 2: Total Tutorial Statements Analyzed**

Name	Total Tutorial statements
Tom	435
Uve	595
Ben	480
Suyuan	689
David	166

A tally of tutorial statements, for each teaching assistant, has been provided in Table 3. A script was done for all five observed tutorial sessions. The statements from the first two tutorials were evaluated from the script only. The third and fourth tutorials were audio tape recorded and the last tutorial was videotaped for evaluation.

Fewer instructor statements were observed for tutorials later in the semester. This was due to several factors. First, students tended to work more independently later in the semester, as they became familiar with the tutorial process. Second, the degree of difficulty for tutorial assignments varied. The last two tutorials, on kinematics, were less difficult. No student groups worked past the scheduled two hour tutorial and some student groups completed the tutorial within one hour.

**Table 3: Tally of Statements from 5 tutorials**

**Tom**

Instructional Statements	Forces 9/23	Momentum 10/26	Energy 11/2	Rotation 11/16	Torque 11/30	TOTAL
1. Probing Questions	16	28	27	6	15	92
2. Leading Questions	23	33	32	12	13	113
3. Direct Instruction	21	26	29	6	15	97
4. Gives feedback	20	16	19	2	10	67
5. Checks Knowledge	5	20	19	5	8	57
6. Group Management	1	0	0	0	0	1
7. Other	2	2	0	0	4	8

**Table 3 Continued: Tally of Statements from 5 tutorials****Uve**

Instructional Statements	Newton 9/28	Momentum 10/26	Energy 11/2	Rotation 11/16	Torque 11/30	TOTAL
1. Probing Questions	0	6	17	7	4	34
2. Leading Questions	0	7	46	44	13	110
3. Direct Instruction	3	5	43	193	38	282
4. Gives feedback	0	4	32	41	9	86
5. Checks Knowledge	0	3	26	22	5	56
6. Group Management	0	0	0	0	0	0
7. Other	0	0	3	20	4	27

**Ben**

Instructional Statements	Forces 9/23	Momentum 10/28	Energy 11/4	Rotation 11/18	Torque 12/1	TOTAL
1. Probing Questions	3	4	3	3	0	13
2. Leading Questions	3	14	10	17	2	46
3. Direct Instruction	24	101	52	51	10	238
4. Gives feedback	12	26	11	24	2	75
5. Checks Knowledge	2	12	6	4	1	25
6. Group Management	0	1	0	0	0	1
7. Other	8	21	25	26	2	82

**Suyuan**

Instructional Statements	Newton 9/29	Momentum 10/29	Energy 11/5	Rotation 11/19	Torque 12/1	TOTAL
1. Probing Questions	2	3	18	9	7	38
2. Leading Questions	3	8	47	45	20	123
3. Direct Instruction	17	13	154	121	80	385
4. Gives feedback	1	14	31	34	22	102
5. Checks Knowledge	2	4	6	17	10	39
6. Group Management	0	0	0	0	0	0
7. Other	0	1	1	0	0	2

**David**

Instructional Statements	Newton 9/29	Momentum 10/27	Energy 11/5	Rotation 11/19	Torque 12/2	TOTAL
1. Probing Questions	7	4	1	3	1	16
2. Leading Questions	4	8	2	12	2	28
3. Direct Instruction	7	24	13	20	18	82
4. Gives feedback	2	2	1	11	3	19
5. Checks Knowledge	3	5	1	2	1	12
6. Group Management	0	0	0	1	0	1
7. Other	1	1	0	5	1	8

The total instructional statements assigned to each category by teaching instructor were summarized for Table 4 and provided as a percentage in Table 5.

**Table 4: Instructional Statements by Category**

Instructional Statements	Tom	Uve	Ben	Suyuan	David
1. Probing Question	92	34	13	38	16
2. Leading Question	113	110	46	123	28
3. Direct Instruction	97	282	238	385	82
4. Gives Feedback	67	86	75	102	19
5. Checks Knowledge	57	56	25	39	12
6. Management of Group	1	0	1	0	1
7. Other	8	27	82	2	8
Total Statements	435	595	480	689	166

**Table 5: Instructional Statements by Percentage**

Instructional Statements	Tom	Uve	Ben	Suyuan	David
1. Probing Questions	21%	6%	3%	5%	10%
2. Leading Questions	26%	19%	10%	18%	17%
3. Direct Instruction	22%	47%	50%	56%	49%
4. Gives Feedback	14%	14%	16%	15%	11%
5. Checks Knowledge	15%	9%	5%	6%	7%
6. Management of Groups	0%	0%	0%	0%	1%
7. Other	2%	5%	17%	0%	5%

### Interrogative Statements

The *Physics by Inquiry* method called for a Socratic dialogue between instructor and student. The professor modeled this strategy in the tutorial training sessions. He rarely gave direct instruction, but he posed questions to individuals or groups to focus work.

Questions, called *probing questions*, categorized his instructional statements.

When the researcher first met with the professor to discuss tutorials, she was given a velocity/acceleration pretest. The sample pretest was accompanied by a barrage of questions from the professor, designed to focus and assist with the pretest. The researcher's reaction was "Wow, this guy is really into his teaching!" In reality, he demonstrated the tutorial process, rather than just describe tutorial instruction.

The professor talked enthusiastically about teaching assistants at University of Washington, who spoke "tutorial like a native tongue." These graduate physics education teaching assistants had worked developing the tutorials and participated in extensive staff meetings. He spoke of one teaching assistant, in particular, who had started as an undergraduate tutorial student in an introductory physics class, after multiple courses in the *Physics by Inquiry* method, he majored in physics and went on to the graduate physics education group. The professor described using this teaching assistant as the "ultimate source" on tutorial teaching dialogue. He also admitted that, when he started work at University of Washington, he had been annoyed by the constant questions, when he "just wanted to know an answer."

Tom, the least experienced teaching assistant, was the most successful in generating probing questions, 21% of his instructional statements were probing questions. David had 10% of statements as

probing questions, other teaching assistants had 3 to 6% probing questions.

Suyuan posed questions that she directly answered, these questions led to direct instruction without opportunity for student answer. Questions were stated as an introduction to verbal instruction, rather than as a question which required a student answer.

The three categories which represented interrogatives were: (1) probing questions to focus attention; (2) leading questions with one obvious answer; and (3) checking knowledge. These three categories were grouped by percentage for each teaching assistant in Table 6.

**Table 6: Percentage Interrogative Statements**

Name	Total Questions type 1, 2 & 5
Tom	62%
Uve	34%
Ben	18%
Suyuan	29%
David	34%

Tom, with 62% of statements in the interrogative, mastered the inquiry methodology to a greater degree than other teaching assistants, who had about one third of instructional statements classified as interrogatives.

Teaching assistants faced a dilemma. While they spoke about tutorial instruction as Socratic dialogue and understood that their role was to pose questions, students constantly asked them

questions. Some students wanted them to "just tell me," and were persistent, sometimes demanding, in their pursuit of teacher explanations. The teaching assistants in this study genuinely wanted to help, guide and assist their students. When students asked them questions, they answered their students' questions.

Early in the semester, at a Monday staff meeting, the issue of direct instruction was addressed. The professor indicated that total group instruction was acceptable when it was apparent that student confusion warranted a "group talk." The instructional statements analyzed were not from group instruction. All statements categorized were from instructor-student or instructor-group dialogues.

### Direct Instructional Statements

Instructional statements to explain a concept or procedure tended to be longer verbal expressions. Table 7 was constructed with the percentage of teaching assistant instructional statements that represented direct instruction.

**Table 7: Percentage Direct Instructional Statements**

Name	Direct Instruction - explains concept or procedure
Tom	22%
Uve	47%
Ben	50%
Suyuan	56%
David	49%

For the majority of teaching assistants, approximately half of instructional statements were direct instruction. Tom kept direct instruction at 22%. As the least experienced teaching assistant, Tom had not been a lab instructor or teacher. He had no instructional experience to rely on; this may have made him more receptive to the modeling provided for the tutorial instructor role. Tom's instructional actions demonstrated the inquiry method with greater facility, as evidenced by the use of interrogatives and avoidance of teaching by telling.

### Student Learning Frustration

Tutorials were designed to challenge misconceptions, to engage students at a sufficiently deep intellectual level and to create a sense of disequilibrium. As Ben described:

(Tutorial) questions ... build on each other ... start on a real fundamental level and through answering these questions, the students are put in situations where they have to use the principles (of physics). Often times they put down their own ideas, as opposed to the correct physics ideas.

Often times the tutorial is set up in a way that the student is asked to put down what they think is correct - and then go through - based on those assumptions - and turn around and on the next page say, find out that they contradict themselves and that sort of thing.

Tutorial instructors were required to review student answers at checkpoints in tutorials, but were also instructed to "let the students

go" during parts of tutorials, so that students, on their own, would become aware of inconsistencies and contradictions.

Student reactions to the process were varied. The majority of teaching assistants spoke of student discomfort and frustration, and felt their job was to help, assist and guide students at that point.

David reported the following incident:

I've seen people get angry, really angry, I've seen people break into tears and the reactions go on and on.

Interviewer: In tutorial you've seen that - tears?

Yes, there was one guy, who's kind of like a football player type guy, a high school tough guy, who had to be trapped into caring and at the end of a tutorial ...

I stopped him at the last question and said, but wait a minute 'I thought this is what's going on' and he put his head down and said 'I thought I was understanding this' and it sounded like he was about to cry.

The rest of his partners were laughing - thinking he was kidding and he raised his head and said 'No, I really thought I had this for a second.'

(That's) what happens when you bring people through a crisis point and then you back away from it, but he had enough invested in it already, at that point, and enough courage, I guess, that I was able to keep him there for a few more seconds - back track real quick - and then he fell on the other side of the divide and then he went and said 'okay wow yah' ... he cared enough to reach the crisis point of his understanding.

Other teaching assistants spoke of student anger and attitude, and recognized that all students did not commit to the intellectual level required for tutorials. Ben said "it's hard to get students to ... work

as intensively as we do in tutorials" and "to think ... for a lot of students it's new to them." One Physics 205 student stated, "This class really makes you think! I don't think that should be required in a 200-level class."

### Student Group Process

Teaching assistants talked extensively about student groups.

Ben described the ideal student group as:

three or four (students) working on the problems together. They're discussing their answers, they're using the models that they draw to help explain to each other what they're trying to say or do.

Very interactive - a lot of talking going on - working together ... generally the groups will be coming to consensus and then the staff will be going around to see - to check on what they came up with - and ask questions based on their answers.

In the first staff meeting following a tutorial, teaching assistants seemed perplexed that students were reluctant to form groups after being told: "get in groups of three." Teaching assistants appeared amazed that students didn't just *get into groups*; they had to repeat, and insist that students move to work in groups of three or four.

Teaching assistants were concerned that students in a group didn't stay together working on the tutorial, students worked at different rates, some fast, some slow. Tom stated:

It's really obvious that some groups work better together than others and unfortunately sometimes- and quite often, I think, some people get in the habit of working in one group and don't jump around to other groups.

Some groups just don't work together. We tried to get students to work with other people - rather than the people they started out with - but they went back to their original people - whether it's working out well or not.

Some groups are working really well together and some groups aren't. And rather than jump into other groups and work with other people they stay in their same group.

Interviewer: Sounds like you tried to get them to move around?

Yes, we tried to do a random thing one week. We had a pretest in tutorial, instead of lecture, and I wrote numbers on top of tutorials and said 'OK I want all the ones over here and the twos here' and it kind of shuffled everybody around.

I was trying to get them to work with other people and maybe find people they would work with better and it seemed like they - the following week - when we went back to freedom of choice - they went right back to the people they worked with (originally).

I don't think they always work in the best group - sometimes you have like one person who isn't up to speed with the group and the rest of the people in the group just leave him behind so you have to go help that person more individually.

In a way, it's OK, but in another way it's really bad - because the whole idea of getting them to work in groups is - from the stand point of getting in the real world - work is in a team with people - so if you can get students to help out other students in their group, it's best.

The students that help out other students learn it better because they'll be teaching it also.

(It) is unfortunate when you walk over and see someone just left behind by their group. It happens a little too frequently. So that's a problem.

Each teaching assistant used different terminology to describe the range of student group types, but all teaching assistants tended to identify three types of student groups.

One type of tutorial group had students that interacted, discussed problems, reached consensus and worked as a team. These groups worked through tutorials as designed. These students put a lot of energy into the process and wanted to master the tutorial concepts.

A second type of group had students working as individuals, who consulted each other or the instructor when encountering difficulties, but did not truly work together on tutorial problems. Uve felt that some of the students

who don't really know the subject ... just listen and (he) has no clue with them. You can ask them and you get no response or somebody else answers. So it's kind of hard to get through to those.

Suyuan believed that students:

first need to understand what (tutorial) is asking them to do ... they need a chance to think by themselves ...

A student who is good, who always (has) answer and ... other student will say 'I like that' and just copy it all.

some of the students who are not so good, will go 'oh, okay' and just accept it.

David said:

You'll see groups from 2 to 6. And I don't discourage that.

The best thing is to let people feel as comfortable as possible. For these students, tutorials were not done by collaborative group.

The third type of tutorial group had students that, Ben described as, "just want to get out fast. Whatever it takes - they'll, you know, pay attention - just to get the answers." David felt these students are in tutorial because "this is what they're expected to be in - but that they don't really want to do it."

Teaching assistants made group classifications dependent on individual student attributes. Teaching assistants felt the majority of students had a good attitude, but that student apathy or student indifference was a problem in student groups.

#### Strategies to Promote Student Group Work

No evidence was observed for teaching assistants use of strategies to promote the group process. However, all teaching assistants were aware of group process as an instructional issue. Teaching assistants talked at length about the nature of student groups.

Students arranged themselves in groups at the first tutorial and tended to remain with that initial group. Tom made an effort, to have students work in different groups, but found students returned

to their original groups. Other teaching assistants, talked about their attempts to have students work in different groups. David said:

I think the best thing is to let people feel as comfortable as possible ... they get established in groups in the first or second week.

it's hard for them to change, even though they may be in a group - where the group is moving too fast or the group is moving too slow -it's more difficult for them to change groups, than it is to put up with that difference in speed. And so I think the comfort level is important.

I'll recommend different things. I'll say 'why don't you go with this group here, because they're more your speed.' I'll recommend things like that, but ultimately the choice is theirs and whatever they feel comfortable with.

And the other thing is large groups. You get the large groups, like (the professor) says, and you get people just along for the ride

And ... I say that's not my job. My job is not to force knowledge on these people. I'll suggest that 'if you're in a group that's a little smaller, you might get a little more out of it. how did you do on your homework? how did you do in your last exam?'

You know, so forth and so on, but I'm not going to insist that they learn the stuff. They're old enough now.

Interviewer prompt on group arrangement:

I haven't seen anyone move because of that (my comments). People who are being carried, know that they are being carried and that's what they want. I had some people try to change groups, because the group they were in was going too fast for 'em and - they tried it for one day and they were back again the next week (back to original group).

They try a new group, but they just don't feel comfortable working in a new setting.

For David, student comfort was an important issue. Student comfort was mentioned six times in David's first interview.

Teaching assistants did not promote the group process for student groups in Physics 205 tutorials. While aware of dysfunctional student groups, teaching assistants simply suggested to students that they "might get a little more out of it" if they worked in another student group.

### Graduate Teaching Assistants' Perspective of Tutorial Instruction Process

#### Teaching Assistants' Perceptions of Inquiry-based Learning

All Physics 205 graduate teaching assistants stated that they had not experienced tutorial or inquiry based instruction as students. They described their educational experiences as "traditional," lecture, seminar and laboratory style instruction. They referred to physics instruction as "plug and chug," driven by substitution of numbers into mathematical formulae to solve problems. Uve openly admitted that he had "no clue as to what tutorial was." Ben stated that he "didn't have much of an idea of how ... it (tutorial) would be different" from being a laboratory instructor.

Tom studied science because of interest generated by research opportunities. He experienced something "like tutorials" when he

worked with a professor who answered his questions "with questions." He was enthused about the tutorial process.

Uve was satisfied with his German education, which he described as systematic and thorough. He didn't think he, personally, would like being a tutorial student. He did believe that 80% of students would benefit from the tutorial process.

Ben liked classes with discussion and believed he would have learned fundamental concepts of physics better by a tutorial method. He felt tutorials gave students a higher level of understanding of the concepts of physics.

Suyuan believed lecture was important. Self study and reading were needed prior to discussion. She described discussions "only ... among the students ... we don't have much discussions (in China)." Her experiences had been in large, impersonal classes. She wanted students to make a serious personal effort, before seeking help from an instructor.

David preferred personalized instruction. His interest in teaching was rekindled by tutorial instruction, he was critical of traditional "cookbook" laboratory exercises.

Working with peers was important to four of the five teaching assistants. David had a hard time starting graduate school because he did not have a working peer group. Tom and Uve, in the first year physics graduate program at MSU, said it would be impossible to get through the work load without working together with other graduate students. They both described routinely working late

nights on problems in the physics building with their peers. They saw the necessity and importance of working together.

Teaching assistants did not mention a connection between their own experience working with peers and the tutorial students work in groups. They liked student tutorial groups that "worked as a team," "stayed together," and "helped each other." Teaching assistants were annoyed when a group "left a student behind" or were insensitive to a student. They felt it was a student responsibility to help each other and to be part of the team. Teaching assistants did not believe it was "their job" to take an assertive role in student group dynamics.

#### Teaching Assistants' Beliefs About How Science is Learned

Each graduate teaching assistant was asked how they think people learn science best. Their answers represented their different perspectives. Tom's answer was:

I don't know. I think it's different for different people. I think some people can get a lot out of reading a book - a text book. A lot of people get more out of labs - seeing the phenomena before their eyes - I'm not sure. I can't make a sweeping statement on that.

Uve gave a complicated answer:

The best way is you know the background ... you know the student and you ... just concentrate on the basics, that he or everybody had to cover ... and I think for students that are not as good or in the (top) 10% of the best then the tutorial thing is really helpful.

especially when I think of students who don't want to be there ... they have to take it ... it's mandatory, (but) - they don't want any pressure ... in this kind of environment, they don't feel the pressure. This kind of thing would really help them to understand ... for 80% (of students) the tutorial way would be the best way to do it.

Ben was slow to answer:

Hum (pause), how they learn best? Well it seems like they - there needs to be a desire to - we require people to learn science and I don't know if that's great - If the general lay person doesn't want to learn science except on a level of just exposing them to what's going on like - like a Popular Mechanics reading about it in a magazine or something that's all they're going to get there needs to be a desire to learn something.

And once that's there, then I think our way, through the tutorials, is a good way. I wouldn't discredit the way I was taught either by intensive problem solving - seems traditionally it's worked, but like I said - the desire is key to both.

Suyuan also answered in terms of motivation:

First, I think they should have (pause) the want to study - they want to study, they are ready. If they don't want study - then no way to help. And I think that is really important, your own - you should study hard. I think there is not much difference ... (in student intelligence) someone who studies and is a good student, not necessarily is really smart.

The effort is important. If everybody put the same effort, I think the results should not be very different. I don't believe so.

David was quick to answer and assertive:

Hard work. They need to do a lot of hard work. The tutorial stuff is - is an attempt to try to adjust the common sense, which is a nice and useful thing to do. But in the end, there is so much science to learn, that a lot of it comes out -- right now - I'm not going to worry about why this makes sense - I'm just going to learn the method of doing it.

I'm going to put in the hard work in order to feel comfortable with that method. And hopefully as I go through it - more and more this one little piece will come into place.

Uve, Ben and David mentioned tutorials in their answers regarding how science is learned. They believed tutorial instruction was important for "some - 80%" people to feel less pressure, a "good way" to "adjust common sense, which is a nice and useful thing to do." The teaching assistants believed motivation, desire, will and hard work were critical to learn science and each alluded to the fact that "it's different for different people."

#### Teaching Assistants' Feelings About Being Tutorial Instructors

Teaching assistants were asked to describe their thoughts when they learned that they would be a tutorial instructor, rather than a laboratory instructor, for Physics 205. Initially teaching assistants thought that tutorial teaching would require more work than being a lab instructor.

I thought it was going to be much more work than being a lab instructor. ... because ... if you do a lab, you do it on your own and you can just do it as quick as you want

the students don't respond that much ... they just do their stuff on their own and you just sit there. Sometimes they don't bother you at all. And, so when I found out (about being a tutorial instructor) - I thought it would be much more work.

A few of the teaching assistants thought they would be "doing similar things," that the difference was how they were supposed to "ask questions and the matter of how to ask questions to get students aware ... to emphasize getting students to think more and through that inquiry to get them (students) to say ... instead of us telling them which is more like labs."

When asked what the experience is like for them as a tutorial instructor - how do they feel? They expressed their feelings about being a tutorial instructor:

Tom:

It's been positive ... I've learned ... my own knowledge of physics has become much better through teaching this way.

Uve:

I like teaching, that's the thing. I feel comfortable teaching.

Ben:

I like it (emphatic statement). It's a good opportunity ... to work with the students and I like that.

Suyuan:

I'm not sure what ... I'm confident in the sense that I know enough to teach. I'm not sure what - if I feel happy or I'm just - yah - zero. (laughs)

(nervous laughter).

*Interviewer note: Suyuan was not comfortable talking about feelings.*

David:

Very positive. It has rekindled my enthusiasm for teaching.

The graduate teaching assistants began the semester with feelings such as Ben's: "I didn't know what I was getting into - I didn't have much of an idea of how - in what ways it would be different (than being a lab instructor)." By the end of the semester, the majority of teaching assistants talked about tutorial teaching as a positive experience.

Graduate Teaching Assistants' Opinions on Training  
Methods for Tutorial Instruction

Teaching Assistants' Beliefs on Existing Training

Each teaching assistant was asked for their opinion on the Monday staff meeting:

Tom:

The meeting is actually critical. Basically everyone is reading from the same page when they're done. And to gauge where the students are at and some of these tutorials have needed some last minute adjustments because of the meetings.

At the Monday afternoon meetings we made changes and the tutorial would have been disastrous without the changes.

Critical interaction. Keep them like they are.

Ben:

Essential. Gotta have that common ground, so that we don't conflict with each other (staff) in the tutorial session.

some of the staff haven't been trained as well as the GTA's. So I think they might benefit a little more from the actual information (physics) that we talk about and the fact that the tutorials are in their infancy as far as being written and developed.

It's necessary to have that meeting, to hammer out problems and a lot of times we omit questions that are ambiguous.

Uve:

That helps a lot. That's the best way to do it, yah.

Just straighten everything out, that's the best thing. I mean you get a lot of ideas when you have 15 people working together. That's the best way.

Suyuan:

I think it's really necessary ... if we don't have a meeting, maybe different TA's might have different - like they don't have - what's the word - maybe the TA's might not have the right understandings.

Especially like (professor) is the instructor. You see different instructor have different ways to approach problem. But I think all the TA's should ... explains the same way.

maybe (the professor) can explain something this way and the teaching assistant can explain it another way, also correct, but maybe that would confuse the student like. Agreement, yah.

David:

Oh I think they're useful. I don't see how we could do without them. I think it's clear that some of the people involved,

whether they're TA's or helpers, don't necessarily get all of it, all the time.

It's a good idea. We should get together in a group and all agree on what the real physics is. So, I don't think we should give that up.

Teaching assistants expressed satisfaction with existing tutorial instructor training.

### Teaching Assistants' Perception of Need for Training

Teaching assistants talked about three sources of training: (1) a university orientation for graduate teaching assistants; (2) a physics department seminar required for first year graduate students; and (3) the Physics 205 staff meetings.

First year teaching assistants participated in a university orientation, a one day seminar for all Graduate Teaching Assistants in the College of Arts and Letters. Tom recalled the "talks were on sexual harassment, grading, legal responsibilities and things to keep in mind as we went along - in relation to the university." David called it:

getting you ready for the fact that you are going into the teacher mode and ... someone talks about teaching ... They say stuff like ... to be an effective teacher you might want to talk a little bit less and ask more questions ... that kind of stuff.

First year graduate students are required to have a Teaching Seminar, with a physics professor. Tom described the seminar as dealing with "a lot of issues," "having some agenda, but frequently

open to problems that we've (physics teaching assistants) run into." Fall 1993, the ten first year physics students had reading assignments from a book the professor was editing and from textbooks to illustrate "shortcomings."

Ben felt the seminar had been a:

probing seminar for faculty to find out how well the (new physics) students perform in front of a class.

It's sort of an exercise, in that you're required to give lectures to the seminar ... so the foreign students with (a problem in) English proficiency get exposed.

Ben wasn't sure if the seminar was used by the department in making teaching assistant assignments, but "you have to pass it and some people don't ... the ones that can't speak English or just can't speak to a group of people for whatever reasons." David said he had some difficulty with the seminar:

that's one of the places I got into some trouble with the instructor (laugh). It wasn't so bad. I was able to keep my tongue tied. He's definitely of the school ... that what we're about is training people.

Interviewer: Even with your teaching experience from Michigan, you had to take the seminar?

Yah. Sounds like they might be doing more (now) than when I had it (four years ago). When I had it, you'd just show up for an hour and they'd try to get us involved in discussions. Most of the time, we didn't bother ... because ... he was just baiting us (so) that he could show us how we were wrong.

So, it was a pretty quiet hour and then we were required to ... present a problem as if we were teaching it. So ... prove that the students could speak English, for one day.

And secondly, to make sure that everyone does, in fact, have a grasp of basic physics so that you could get thrown in the Help Center. And not be worried if you were going to screw people up or not (laughs).

Since the teaching assistants had taken the teaching seminar different years they had varied perceptions of the experience. Two teaching assistants mentioned language ability of foreign graduate students was evaluated in seminar. Three teaching assistants said teaching performance was assessed in seminar as each student had to present a sample instructional lesson to the seminar.

The teaching assistants had expected staff meetings for Physics 205. Some of the teaching assistants described their experiences in meetings as laboratory instructors for other courses. They "liked the meetings" for Physics 205. Ben said:

I ... like ... the kind of response that (the professor) gets. When we're in there it seems like everybody is alert and willing to contribute their knowledge and opinions on the tutorials.

He's writing them (tutorials) - he's coming up with all this information - and putting it down in this manner on the tutorials. And he needs a lot of input. And the way he gets it, I think is great, he gets a lot of response out of his staff.

If I was doing it, if I was in his shoes, I'd definitely want it to be like that.

The teaching assistants were supportive of the Monday staff meetings, anticipated them as part of the graduate teaching assignment, saw them as essential, and supported them as they existed.

The term *training* was used negatively by David throughout both interviews. Suyuan was unsettled by the notion that physics graduate students required *training* for the role of tutorial instructor. While staff meetings were part of all Graduate Teaching assignments, the notion of *training* created negative responses from two teaching assistants.

### Teaching Assistants' Preference for Training

The teaching assistants were asked to suppose that they were in charge of training tutorial instructors for the future, possibly the next year: "what would you like to see happen to assist graduate teaching assistants?" Tom responded:

I think I wouldn't be able to make any specific improvements at this time. I had no teaching experience going in - essentially no teaching experience - and I had a few rough spots here and there, but got through okay.

Uve stated:

You get the tutorials and then you work through the tutorials, there's no set up. Yah, I would do it the same way. Everybody writes down their own answers so everybody should be set.

(the professor) does one (tutorial) with me so - I'm all set.

Interviewer: You like the input from the staff at the Monday meetings?

(nods. yes) OH, I did that, I changed a lab.

Where we needed to know masses to have it make sense. If you're going to solve it, you solve it all the way through, so I just gave them masses.

Yah - (tutorial) was too hard and the homework was too hard too - I just changed it and they write it down that I authorized to change this.

Ben said:

I would like to see the kind of response that (professor) gets. When we're in there it seems like everybody is alert and willing to contribute their knowledge and opinions on the tutorials. And the way he gets it, I think is great, he gets a lot of response out of his staff. If I was doing it, if I was in his shoes, I'd definitely want it to be like that.

Suyuan responded:

Um (long pause) I think mainly everybody has their own teaching style. (pause) I think the most thing is depends on the persons own ... like how well he understands that. I can't think of anything else.

Interviewer: I was asking what if I was giving you the job of training the new people? What would you do?

Do you think we need to be trained?

Interviewer: What do you think?

*INTERVIEWER NOTE: APPEARS DEFENSIVE - THE WORD TRAINING IS RED FLAG HERE!*

Because I'm, when I'm a tutorial (instructor), I'm not trained I just come here.

Yah. Like ... all TA's can be in the help center you don't train them to come. The basis is that they understand physics - undergraduate physics and they can be qualified (to work in the) Help Center.

David said:

I'd do it pretty much the same way. I'm not so sure I would insist that we do it in groups of three or maybe do it in a large group. I'm not so sure which one has more value or less value.

I would definitely go over what we agree as being the true physics.

The stuff that would be really fun, for me, would be going over the tangents - going over the different digressions - you know that probably wouldn't come up in tutorial.

So ... let's spend some time going over and agreeing on what the real physics is for a given question, and then talk about - check out this problem here - and it's where we're doing this and is it still true - what we're saying is really 'what's happening here.'

stuff like that ... be more creative that way. And that would be fun.

Interviewer: The staff would do brainstorming - and take a holistic look at physics - you would add that?

I don't know if I'm creative enough to do that.

Interviewer: Do you think that would help the tutorial instructors to have a better feel for tutorial process?

What's crucial in what we do is being flexible enough to let the students do it their own way. That's still - you know, there is one set of laws in Newtonian Physics, but there is many ways to do a problem with those laws.

The teaching assistants had few suggestions to change tutorial instructor training. Teaching Assistants' held a preference for the existing staff meetings.

The Role of the Graduate Teaching Assistant as Instructional  
Support Staff in Large Introductory Science Classes

Graduate Teaching Assistants' Beliefs About Their Instructional Role

The majority of teaching assistants believed students learned more from the tutorials than from laboratory. David stated:

I like asking the questions, over and over again, on a single topic.

Each week, it's one very simple thing. Like one week it was writing down the symbol to represent Force, to recognize that it's a force by something on something.

Very simple idea, but we can dress it up in lot of different circumstances, and it's the same idea.

I like ... the idea of focusing on just one thing and ...when you get to the exam, it's only one or two ideas on any given exam, but (the professor) dresses it up in different fashions.

It's not just a bunch of things they have to memorize - that they're not synthesizing. I think that's what's working.

Tom and Ben both expressed the belief that "they were doing better at getting the point across, than the traditional way." Uve thought that tutorials were better than laboratories, to help most students understand physics concepts.

The majority of teaching assistants liked "the interaction" and felt satisfaction from helping students in tutorials. They found the experience of guiding and assisting students in tutorials different

from laboratory teaching. "It's quite satisfying when people do get stuff that they wouldn't have gotten. That's satisfying."

Many of the teaching assistants were enthused about being part of something new, a "revolutionary way of doing things." Some said they were excited about the tutorial system. They felt they had "promising results" and believed in the "success" of the tutorial method, *Physics by Inquiry*.

### Proposed Methods of Training

Teaching assistants were satisfied with the training provided. They had liked working in Physics 205, as tutorial instructors. The majority expressed a preference for working with this professor. They felt a collegiality among the staff. When asked their opinion of training they were "satisfied" and could make few suggestions to change or improve training of teaching assistants for tutorials.

The original plan for the staff meetings was as follows: (1) take the student pretest; (2) review student answers to the pretest; (3) work through the tutorial; (4) edit tutorial for ambiguous questions, acknowledge and correct tutorial glitches or snags; (5) identify instructional strategies for specific portions of tutorial, such as "ride herd close on page 2, but let them run with it on page 3" to elicit and confront inconsistencies or misconceptions; (6) establish student goals for the tutorial. The process called for teaching assistants to do the tutorials *like students* in small collaborative groups reaching

consensus on tutorial problems. This allowed the professor to model the role of the tutorial instructor.

In staff meetings for Physics 205, the professor had an egalitarian tone and encouraged two-way communication. At each meeting the professor sought staff concerns, respected contributions, and welcomed suggestions. He frequently asked questions about the tutorial process from the staff's perspective. Part of every meeting was dedicated to debriefing the previous tutorial. He also shared Physics 205 student comments, notes and feelings with the staff, both positive and negative.

The staff took a tutorial pretest and reviewed sample student pretests at each meeting. The plan was to have staff do the tutorial, in teams of three, like the student groups, with the professor taking the instructor role, questioning groups and encouraging dialogue and team effort to grapple with the concepts of each tutorial. This procedure was not followed for all tutorial meetings.

At some meetings, tutorials were done as a whole group and some tutorials were split - part of the tutorial done as small groups, part of the tutorial done by the group as a whole. Going through tutorials as a large group took less time. This was necessary, because meetings began at four o'clock and the professor wanted each meeting to conclude by six o'clock.

Due to the two hour time constraint, it was not always possible to have each small group finish the tutorial, plus step back into the instructor's role to talk about strategies to guide the tutorial process.

The professor preferred that staff experience the tutorials as small groups and then review the tutorial as instructors. He wanted teaching assistants to experience doing the tutorials "like the student groups." He elicited the staff to contribute to rewriting ambiguous questions and generally "debugging" tutorials adapted for this algebra-based physics course from a calculus-based physics course. He wanted staff to be aware of specific or unique instructional strategies appropriate for each tutorial.

Problems occurred when Monday holidays caused the tutorial staff meeting to be scheduled the preceding Friday. All staff could not attend a Friday meeting. The tutorial following Labor Day weekend was marked by student confusion due to lack of staff consensus. Having staff agreement on tutorial answers became a priority for the tutorial staff meetings.

In addition to addressing general staff issues, taking a pretest, reviewing students' pretest, it was essential that staff meetings provide a common tutorial answer guide for instructors.

The professor wanted to incorporate the components of training sessions from University of Washington, although a shorter time period had been allotted. He recognized that more time was needed to accomplish his agenda. To streamline the staff meetings, portions of many tutorials were done as a large group effort, without modeling the interrogative instructor role.

### Appropriate Instructional Strategies Modeled

The teaching assistants in this study articulated that tutorial method required instructors to use Socratic questioning:

asking questions ... how we're supposed to ask the questions and get the students aware. We're trying to get the students to think more and through that inquiry ... get them to say ... instead of us telling them.

They recognized that tutorial teaching was different than laboratory instruction. The *Physics by Inquiry* method has instructors guide the learning process by questioning individual students or student groups to focus attention, to guide thinking and to monitor with interrogatives. Teaching by direct instruction or "telling" is to be avoided. Analysis of instructional statements for the five teaching assistants demonstrated that most teaching assistants used about one-third interrogative statements. Approximately half of teaching assistant instructional statements consisted of direct instruction.

Teaching assistants recognized that it was "hard to get the students to sit down and work as intensively as we do in tutorials." Ben expressed that "for a lot of students it's new to them ... they haven't had to say very much - and to think about physics, for some people, is the worst possible nightmare that they have to get through."

The teaching assistants in this study were aware that many student groups experienced difficulties doing tutorials in the

collaborative method proposed. Teaching assistants did not use group management techniques or believe that student group management was their responsibility.

## CHAPTER 4

## IMPLICATIONS, DISCUSSION AND RECOMMENDATIONS

Introduction

The American Association for the Advancement of Science (1990) and National Science Teachers Association (1992, 1993) envision new instructional strategies that rely less on memorization and established procedures and place more emphasis on conceptual understanding. The current goal for science and mathematics teacher education is preparation of educators who will accomplish this vision by altering content and reframing instruction with the active engagement of students in inquiry, problem solving, real world applications and appropriate uses of technology. To meet this goal, pre-service science and mathematics teachers need experience in content courses using alternative instructional strategies for mathematics and science.

The introduction of *Physics by Inquiry* tutorials in Physics 205 was a course revision consistent with this goal to improve undergraduate pre-service teacher education at Montana State University. The implementation provided a student centered inquiry-based component in an introductory physics course for secondary education majors, as well as other undergraduates enrolled in Physics 205, fall 1993. Physics graduate teaching

assistants were tutorial instructors. It was important to know if the training provided for physics graduate teaching assistants was sufficient to accomplish the objectives of the *Physics by Inquiry* tutorial method.

Qualitative research methods were used to accomplish the four purposes of the study:

- (1) to determine if the *Physics by Inquiry* method was modeled by graduate teaching assistants' actions in Physics 205 tutorial sessions;
- (2) to describe the tutorial instruction process from the perspective of the graduate teaching assistant;
- (3) to determine physics graduate student opinions on training methods for tutorial instruction;
- (4) to develop a frame of reference which can be used by university faculty to better understand the role of the graduate teaching assistants as instructional support staff in large introductory science classes.

This chapter conceptualizes how this information might be used to construct a model for training teaching assistants who are required to teach in an instructional method which they have not experienced as students.

This chapter is organized as follows. First, implications and discussion will be presented relative to teaching assistants as *Physics by Inquiry* instructors. Then, several conceptual and practical implications of the findings related to the teaching assistants

perceptions of the tutorial instruction process will be reviewed. Then, opinions on teaching assistant training suggested by the graduate teaching assistants will be presented. Finally, recommendations will be made for the selection and preparation of graduate teaching assistants for their role as instructional support staff in large introductory science courses, especially courses implementing new instructional models.

#### A Footnote on Generalization

The results of this study were site specific, to a considerable extent. Although the study's findings could be generalized under certain circumstances, the research design used does not allow casual generalization. Even the appropriateness of generalizing to other science departments cannot be taken for granted.

#### Implications and Discussion

##### Teaching Assistants as *Physics by Inquiry* Instructors

Teaching Assistants' Instructional Dialogue. Teaching assistants did not demonstrate a predominant use of interrogatives or Socratic dialogue in Physics 205. A clear pattern of teaching by direct instruction was observed in tutorials. This contrasted with the

preferred method of engaging students in a Socratic dialogue to guide them through tutorial problems.

The analysis of teaching assistant instructional statements demonstrated that use of Socratic dialogue was not the norm in Physics 205 tutorials. In formal interviews with the researcher, teaching assistants verbalized that their tutorial role was to guide student learning by presenting probing questions to focus student attention. From observation and analysis of 2,365 teaching assistant instructional statements, 193 instructional statements were posed as probing questions, while 1,084 or almost half of all instructional statements were direct instruction. Since the direct instructional statements tended to be longer verbal exchanges, a considerable portion of instructor verbiage was didactic teaching.

Management of Group Process. Teaching assistants did not use strategies to promote student group process. The teaching assistants believed that it was a student responsibility to participate in and contribute to their group. Teaching assistants were aware of student group difficulties: lack of collaboration, little discussion, working at varied rates, and failure to engage in team effort.

The majority of teaching assistants worked in study groups with other physics graduate students. Participation in study groups was essential to their success in physics graduate school. Teaching assistants didn't think they could "get through" the demands of the

physics program without teaming with other students doing problems.

Teaching assistants did not describe or express any parallels between their own study groups and the tutorial student groups. Either they were not cognizant of the similar group expectations, or they didn't sense any relationship between their study groups and the Physics 205 student tutorial groups.

All teaching assistants talked about problems in student tutorial groups and the existence of dysfunctional student groups. In the considerable discussion of student tutorial groups, teaching assistants did not draw any comparison between their personal need for peer group study as learners and tutorial student groups.

Perhaps it is their dependence on and belief in study groups that explains their annoyance with undergraduates who did not contribute to their tutorial groups. The teaching assistants expressed displeasure with students who "left people behind," did not "stay with the group," or failed to participate as a contributing group member. Teaching assistants felt individual students should be responsible to their group.

If the *Physics by Inquiry* method depends on student participation in a collaborative group, then teaching assistants require an understanding of group process and strategies to enhance student group process. Since teaching assistants did not promote group process for students in Physics 205, this may suggest little knowledge of group process or lack of skill facilitating group process.

Instructor Experience. Teaching assistants were on a continuum from *no teaching experience* to considerable teaching experience as laboratory instructors or lecturers. The instructor with no previous teaching experience demonstrated the most facility with the *Physics by Inquiry* method. He used probing questions to a greater extent than the experienced instructors. This may suggest that no previous teaching experience allows teaching assistants to be more receptive to training.

Odom (1974) found that teachers with extensive classroom experience tended to be more resistant to altering practice and implementing new models of instruction. He found a negative correlation between change in teaching strategies and length of teaching experience after teacher participation in the Institute for Physics at University of Northern Colorado. Teachers with little or no physics teaching experience more readily adopted the methods promoted by that summer workshop on physics teaching.

#### Graduate Teaching Assistant Perspective

What teaching assistants thought and believed about learning science impacted their tutorial teaching actions. Considerable variability in graduate teaching assistants was noticed. They had discrepant experiences as students, beliefs about learning, and

background as instructors. Their performance as tutorial instructors was in accordance with their educational experiences.

Teaching Assistant Background. The teaching assistants in this study presented a considerable diversity in personal and educational background. According to Lortie(1975), Ziechner & Tabachnick (1981) and Lasley & Applegate (1982) direct school experiences impact prospective teachers. Teaching performance is dependent on what teachers think about teaching, believe about learning and experience as teachers and learners. Each teaching assistant in this study had unique beliefs and experiences. There was no pattern of similarity or duplication of history among the physics graduate teaching assistants.

Teaching assistants described their experiences as traditional instruction and stated that they had no experience with student centered or inquiry-based instruction. They described *informal science learning* experiences in peer study groups, work study positions, small individualized classes, independent study options, employment in laboratories, or association with science educators.

Teaching assistants did not believe they had student experience "like tutorials." In their formal education, they were correct, they had not experienced tutorial instruction: student centered, inquiry-based models of instruction. In informal learning, however, they described a myriad of experiences that offered science learning opportunities akin to tutorial instruction.

Only one teaching assistant recognized and expressed "something like tutorial" with an undergraduate physics professor: "If something wasn't working right he would ask you questions. And you'd end up answering your own question. Well, it's almost like the tutorial - you end up answering your own question - so I learned more from him that way." Other teaching assistants drew no comparisons between their personal educational experiences and the tutorial model of instruction.

The lack of teaching assistant experience with models of instruction, such as *Physics by Inquiry*, may be a contributing barrier to their adoption of the preferred instructional method. Education reformers recognize that teacher preparation cannot simply suggest new method, but pre-service teachers need experience as learners with new methods (Huling & Hall, 1982; Anderson & Smith, 1986; Novak, 1987; Novak & Ridley, 1988; Cohen & Ball, 1990).

Articulated Tutorial Instructor Role. Teaching assistants' description of what they did as tutorial instructors was not consistent with their tutorial instruction actions. Brickhouse and Bodner (1989) reported a similar phenomena for a beginning science teacher: instructional behavior inconsistent with espoused beliefs.

Teaching assistants articulated the concept of tutorial instruction as Socratic dialogue to guide the student process. They

verbalized their instructional role as asking questions, getting the students to think, and having students work in collaborative groups.

Teaching assistants were adept in articulation of the preferred instructor role for tutorial teaching. Teaching assistant actions in tutorial were not consistent with the tutorial instructor role described to the researcher.

### Teaching Assistant Opinions on Training

While teaching assistants did not model the preferred tutorial instructor role, teaching assistants expressed satisfaction with the *Monday Staff Meetings*. They believed they were prepared for the role of tutorial instructor. They did not perceive a need for training or make recommendations for tutorial instructor training.

The term *training* held negative connotations with several physics graduate teaching assistants. Teaching assistants in this study were enthused about tutorial instruction and felt they were doing a "better job" teaching, than with traditional laboratory instruction.

### Recommendations for Practice

Reform of science and mathematics content courses is, in part, dependent on graduate teaching assistants' facility with methods of instruction, such as *Physics by Inquiry*. Teaching assistants have not

experienced these methods as students. If graduate teaching assistants are to successfully teach university students with new models of instruction, several recommendations can be made relative to the selection and training of graduate teaching assistants for new instructional roles.

### Selection of Teaching Assistants

Interview. Screening prospective teaching assistants by interview to determine their learning history and beliefs about learning is recommended. Interview information would provide guidance in selection of teaching assistants that are more likely to adopt an instructional strategy consistent with their experience and beliefs.

In this study, the only teaching assistant reporting a "tutorial like" experience articulated that it had been a powerful learning opportunity. That teaching assistant adopted the tutorial questioning strategy and demonstrated a greater facility with interrogatives than other teaching assistants. Teaching assistants, satisfied with learning from lecture style instruction, tended to use a didactic teaching style.

Employ Inexperienced Instructors. In this study, the teaching assistant with no experience modeled instructional actions supporting inquiry-based learning better than teaching assistants with one to seven years of instructor experience. This may suggest

that inexperienced teaching assistants are more receptive to proposed and modeled instructional methods.

If new styles of instruction are envisioned for a teaching assistant, then selection of inexperienced teaching assistants might be preferred. Inexperienced teachers may adopt proposed instructional strategies more readily (Odom, 1974). New teaching assistants would have no teaching experiences to depend on or old behaviors to rely on. As teaching neophytes, new teaching assistants might be more receptive to proposed and modeled instructional strategies.

### The Term *Training*

Nomenclature such as *staff development* or *staff meetings* should be employed. The term training had a negative connotation for some teaching assistants. One teaching assistant displayed open hostility at the notion that teaching assistants "need to be trained."

While a training component is essential in weekly pre-tutorial staff meetings, the title Staff Meeting must be retained. Course staff meetings were routine for teaching assistants in this physics department. The researcher began the study calling the Monday meetings teaching assistant training sessions. As the study progressed, the researcher consciously began to refer to the Monday pre-tutorial meetings as Staff Meetings. Avoiding the name training did not imply or suggest that training was to be avoided, but

circumvented apparent negative connotations and hostility with the concept of training.

### Practical Implications for Training

Teaching Assistant use of Socratic dialogue and group management appears unlikely without expansion of the training component for tutorial instructors.

The original plan for the staff meetings was as follows:

- (1) take the student pretest;
- (2) review student answers to the pretest;
- (3) work through the tutorial in small collaborative groups;
- (4) refine and edit tutorial worksheets;
- (5) identify instructional strategies to *elicit, confront and resolve* student misconceptions;
- (6) establish student goals for the tutorial.

The process called for teaching assistants to do the tutorials *like students* by collaborative group effort to reach consensus on tutorial problems. This would allow the professor time to model the role of the tutorial instructor.

This plan for training teaching assistants was not adhered to fall, 1993. The meetings were scheduled to last two hours. The agenda was not kept because sharing tutorial instructor staff information, debriefing the previous tutorial, and assorted, necessary

course housekeeping chores, such as answering homework grading questions and establishing schedules, occupied much of the meeting time.

In order to stay within the two hour time frame, few tutorials were done entirely as small groups. Most often, the two hour time constraint required that tutorials be done as a single, large staff group. Modeling of the tutorial instructor role was minimal and teaching assistants did not have a student tutorial experience.

Provide Time for Student Type Tutorial Experience. In an effort to ameliorate the effects of Teaching Assistants' long history of learning experiences with didactic teaching, teaching assistants need a *student type* experience doing tutorials. The inquiry method of teaching should be modeled so that teaching assistants might gain student perspective and observe desired tutorial instructor actions.

The training of tutorial instructors, for physics graduate students who have not used *Physics by Inquiry* as students, must provide the tutorial experience for teaching assistants. Time for teaching assistants to experience inquiry-based learning, or any new instructional model is essential. Training should include role-play or simulation to provide experience with the instructional model.

In programs designed to have "teachers give up responsibility for getting students to the answer" there has been considerable variation in practice after training (Wilson & Ball, 1991). Significant and specific changes in teaching tended to occur only when teachers

themselves became active constructivist learners (Wilson & Ball, 1991, p. 34). If teaching assistants are able to recognize that a teaching strategy has enhanced their learning, they are more likely to incorporate that strategy into their instructional repertoire.

Tutorial instruction by the *Physics by Inquiry* method, requires that teaching assistants develop facility with questioning strategies. Increasing the time allotted for the weekly staff meeting, incorporating the original component of role-play or simulation to provide experience with the instructional model, is critical. Coupled with guided practice as mock tutorial instructors, teaching assistants would have *student experience* and *teaching skills practice* with tutorials.

Appropriate Training Methods. Methods which adult leaning theorists suggest are appropriate to improve performance include conference discussion, role-play and simulation (Knox, 1986; Brookfield, 1987). An informal atmosphere, feedback and active involvement of the learner promote the effective learning conditions recommended by Long (1983).

Mezirow (1981) challenges the teacher of adults to be sensitive to the idiosyncrasies of each learner. Teaching assistants provided no single profile, but rather demonstrated a wide range of cognitive, personality and experiential characteristics. Plans for tutorial instructor training must incorporate the notion of variability in adult

learners and incorporate methods appropriate to improve performance.

Educate for Critical Reflection. Education to enhance teaching assistants' self-reflection is recommended. Reflection would challenge the teaching assistants to explore alternative ways of thinking and acting (Schon, 1983; Mezirow, 1991). It would foster transformative learning or taking action to implement insights. Promoting self-examination would strengthen the teaching assistant in the process of critical thinking, by assessment of practice, by acknowledgment of the complexity in the tutorial setting and by enhancement of personal theory building.

In this study, instructional behavior was inconsistent with espoused beliefs. Intensifying self reflection for the teaching assistant is proposed to assist in the confrontation of this paradox.

Peer Coaching. Incorporate peer coaching or peer observations into teaching assistant training. Observations should be focused on specific teaching actions or behaviors that teaching assistants have selected or identified as important or useful in tutorial teaching.

Teaching assistants are likely to select actions or behaviors consistent with the instructor role articulated in this study. Teaching assistants verbalized the preferred instructional role. If asked "what to look for" in peer observation, it is likely that teaching assistants

would generate appropriate instructor behaviors, actions that teaching assistants readily described to this researcher.

Peer observation or peer coaching would provide a forum for teaching assistants to confront the discrepancy between espoused instructional role and observed instructional actions reported in this study.

Group Management. An additional strand of training on group process and specific strategies to promote student group process would be useful for tutorial instructors.

Teaching assistants in this study recognized and applauded students working cooperatively in tutorial groups. They did not believe that it was *their job* to promote student group process and did not take instructional action to manage student groups.

Most teaching assistants held a strong personal belief in study groups, but lacked enough understanding of group process or management skill to promote student group process.

### Summary of Recommendations

Some practical implications exist for training teaching assistants to be tutorial, *Physics by Inquiry*, instructors. Some of the training suggestions may be appropriate for any teaching assistant required to use instructional methods that they have not experienced as students.

1. Interview prospective teaching assistants to determine if educational experiences and beliefs are consistent with and supportive of new methods.
2. Employ inexperienced teaching assistants, who have not established a personal instructional pattern and who might be more receptive to training.
3. Continue to call training sessions *Staff Meetings*.
4. Increase the time allowed for staff meetings so that teaching assistants experience tutorials *like students* with role-play or simulation and modeling of the preferred instructor role.
5. Expand training with simulation and role-play of tutorials, conference discussion and other adult learning strategies appropriate to improve instructional performance.
6. Educate teaching assistants for reflection.
7. Incorporate a plan for peer observations or peer coaching with tutorial instructors.
8. Include training on group process and group management.

#### Recommendations for Future Research

Teaching assistants in this study were enthusiastic about tutorial instruction and felt they were doing a better job teaching, than with traditional laboratory instruction. They were confident that this method of instruction improved student understanding. Future research on teaching assistants is recommended to include: a

longitudinal study, a study with larger numbers of teaching assistants and a study of teaching assistants balanced for gender.

The Physics 205 professor's preliminary investigation of student satisfaction and student achievement, at the end of fall semester, 1993, suggests improvement in both areas (Francis, 1994). A future study of student achievement is warranted.

The instructional staff for Physics 205 included one or two undergraduate work study students in each tutorial section. The graduate teaching assistants were the lead teachers, but work study students were employed to accomplish a 7:1 student/teacher ratio in tutorials. This study did not focus on the undergraduate work study students. Work study students had taken Physics 205 the previous year with the professor. He selected them as tutorial assistants in fall 1993, not only for their knowledge of physics, but also, for their *people skills*.

These undergraduates had experience with tutorials piloted in 1992-93. Many of the work study students were adept at tutorial instruction. This casual judgment, from researcher observation, was confirmed by the professor's opinion. An investigation of work study students' role as instructional support staff for physics tutorials could determine if this observation was valid. If work study students are evaluated to model tutorial teaching effectively, this would be consistent with the notion that effective instruction with a teaching model requires student experience with the model and belief in the method.

During the fall 1993 semester, students in Physics 205 were noticed to evolve as tutorial participants. Initial student hesitation was observed and attributed to the new set of expectations. Students seemed to develop a facility with tutorials later in the semester. A case study on the evolution of students as tutorial participants in inquiry-based instruction might be useful as a contribution to the design of tutorials, tutorial instructor training and development of student assistance strategies.

#### Concluding Statement

This study determined that the teaching assistants did not model the *Physics by Inquiry* method with Socratic dialogue and management of student group process. Teaching assistants verbalized appropriate instructional actions, but were observed to use a predominantly didactic teaching style.

Graduate teaching assistants in this study presented a variety of perceptions and beliefs about inquiry-based learning and how science is learned. They felt comfortable in the role of tutorial instructor. They spoke positively about their tutorial teaching and had confidence that their students in tutorials "learned more" than students in traditional introductory physics laboratories.

A clear pattern emerged from this study. Teaching assistants were adept in articulation of the preferred instructor role for tutorial teaching. They were satisfied with the training methods provided

for their role as tutorial instructors. They had few suggestions to change or improve training for future tutorial instructors. However, teaching assistant actions in tutorial were not consistent with the espoused tutorial instructor role.

A concurrent theme of teacher action dependent on teacher beliefs was sustained throughout the study. The teaching assistant actions, as tutorial instructors, reflected their educational beliefs, background as students and learning experiences. They described their student experiences, explained their learning theories and were observed to teach according to those perceptions. Their performance as tutorial instructors depended on what they thought and believed about learning science.

Some practical implications exist for training teaching assistants to be tutorial, *Physics by Inquiry* instructors. Training suggestions recommended may be appropriate for any teaching assistant required to use instructional methods that they have not experienced as students.

Recommendations for selection and training teaching assistants include the following: Interview prospective teaching assistants to determine educational experience and beliefs. Employ inexperienced teaching assistants whose perspectives match the proposed instructional role. Incorporate training into staff meetings. Provide time and opportunity for teaching assistants to experience the instructional model with simulation or role play, accompanied by conference discussion. Use strategies known to enhance adult

learning and that are sensitive to the variability of adult learners. Educate for critical reflection. Incorporate a system of peer coaching or peer observation. Include a teaching assistant training component in group process and group management.

Redesign of university science instruction is likely to involve graduate teaching assistants as instructors implementing student centered instruction and innovative models of teaching. This study concluded that graduate teaching assistants require carefully planned and executed training. Staff development, including student type experience with the model of instruction and instructor practice with the delivery of instruction, is essential if specific teaching actions are required by an instructional innovation.

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**APPENDICES**

**APPENDIX A**  
**RESEARCH QUESTIONS & RELATED**  
**PROCEDURES AND METHODS**

RESEARCH QUESTIONS & RELATED PROCEDURES AND METHODS

**PURPOSE ONE:** To determine if the *Physics by Inquiry* method is modeled by graduate teaching assistant actions in Physics 205 tutorial sessions.

QUESTIONS

RELATED PROCEDURES & METHODS

1. Do teaching assistants guide the student problem solving session by using appropriate questioning strategies?

Field observations of tutorials  
Audio-tape recording of tutorials  
Data Analysis

2. How often do teaching assistants use direct instructional strategies?

Field observations of tutorials  
Audio-tape recording of tutorials  
Data Analysis

3. Are teaching assistants sensitive to student learning frustration level during tutorials?

Field observations of tutorials  
Audio-tape recording of tutorial  
Data Analysis

4. Do teaching assistants promote student group process?

Field observations of tutorials  
Data Analysis

5. What strategies do teaching assistants use to promote student group process?

Field observation of tutorials  
Data Analysis

**PURPOSE TWO:** To describe the Tutorial Instruction Process from the perspective of the Graduate Teaching Assistant.

QUESTIONS

RELATED PROCEDURES & METHODS

1. What are GTA perceptions of inquiry-based learning?

Informal Interviews  
Formal Interviews  
Field Observations  
Data Analysis

2. What are GTA beliefs about how science is learned best?

Formal Interviews  
Data Analysis

3. How do GTA's feel about their role as tutorial instructors?

Formal & Informal Interviews  
Field Observations  
Data Analysis

**PURPOSE THREE:** To determine physics graduate student opinions on training methods for tutorial instruction.

**QUESTIONS**

**RELATED PROCEDURES & METHODS**

- |                                                                 |                                                           |
|-----------------------------------------------------------------|-----------------------------------------------------------|
| 1. Do GTA's believe existing training meets their needs?        | Informal Interviews<br>Formal Interviews<br>Data Analysis |
| 2. Do GTA's perceive a need for training?                       | Informal Interview<br>Formal Interviews<br>Data Analysis  |
| 3. Is there a GTA preference in method for in-Service training? | Informal Interviews<br>Formal Interviews<br>Data Analysis |

**PURPOSE FOUR:** To develop a frame of reference which can be used by university faculty to better understand the role of Graduate Teaching Assistants as instructional support staff in large introductory science classes.

**QUESTIONS**

**RELATED PROCEDURES & METHODS**

- |                                                                                                                            |                                                                                                                          |
|----------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| 1. What are GTA beliefs about their instructional role?                                                                    | Informal Interviews<br>Formal Interviews<br>Data Analysis                                                                |
| 2. What methods of training are proposed for GTA's?                                                                        | Informal Interviews<br>Formal Interviews<br>Field observations of tutorials<br>Data Analysis                             |
| 3. Do GTA's model appropriate instructional strategies in Physics 205 tutorial sessions after TA weekly training sessions? | Field Observations of tutorials<br>Audio-tape recording of tutorials<br>Formal Interview with Professor<br>Data Analysis |

**APPENDIX B**  
**SAMPLE PHYSICS 205 TUTORIAL PRETEST AND**  
**SAMPLE PHYSICS 205 TUTORIAL**

## Sample Physics 205 Tutorial Pre Test

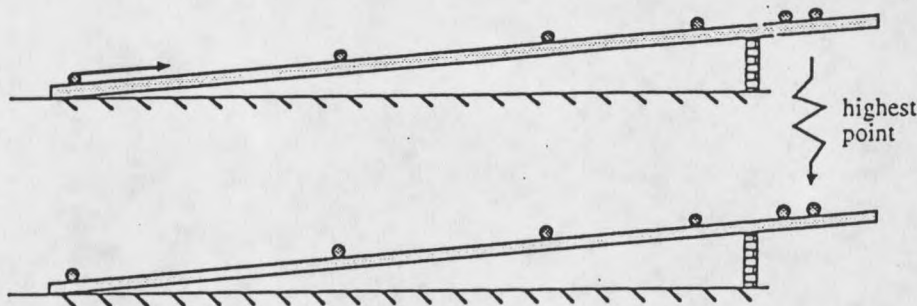
Physics 205

Pretest #1

Name \_\_\_\_\_

1. Observe the motion that is demonstrated at the front of the room.

- A. The diagram below represents a strobe photograph of the motion of the ball as it rolls up and then down the track. (In a strobe photograph, the position of an object is shown at instants that are separated by equal time intervals.)



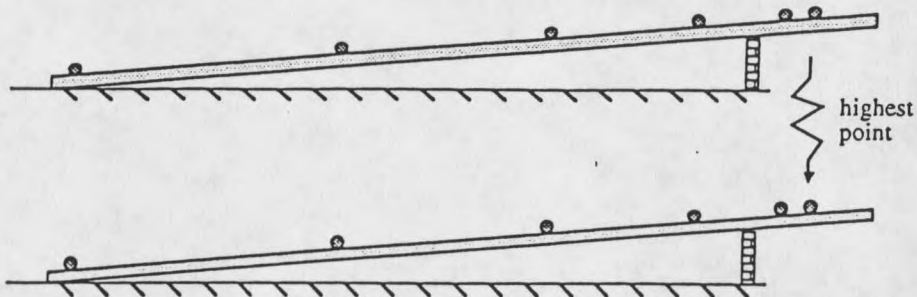
How can you account for the arrangement of dots on the diagram?

- B. The arrow on the diagram above represents the velocity of the ball at the first location. At each of the other locations shown, draw vectors to represent the *velocity* of the ball at those locations. If the velocity is zero at any of the locations, indicate that explicitly.

Briefly explain why you drew the arrows as you did.

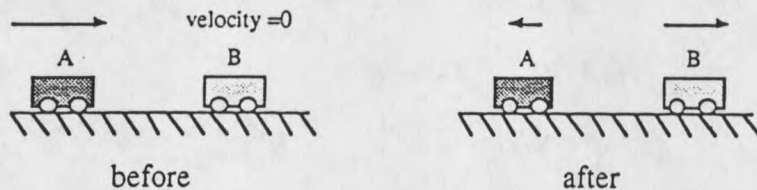
### Sample Physics 205 Tutorial Pre Test

- C. The previous diagram has been reproduced below. At each of the locations shown draw vectors to represent the *acceleration* of the ball at those locations. If you know the magnitude of the acceleration at any of the locations (for example, if the acceleration is zero, etc.), indicate that explicitly.



Briefly explain why you drew the arrows as you did.

2. A cart on a table (Cart A) collides with another cart that is initially at rest (Cart B). After the collision both carts are moving. The diagrams below represent snapshots of the carts before and after the collision.



The arrows on the diagrams indicate the velocity vectors of the carts at the instants shown.

Consider the time interval between the two instants shown.

- During this interval, is the magnitude of the average acceleration of Cart A greater than, less than or equal to the magnitude of the average acceleration of Cart B? Explain how you can tell.
- During this interval, is the direction of the average acceleration of Cart A the same as, or different from, the direction of the average acceleration of Cart B? Explain how you can tell.

## Sample Physics 205 Tutorial

Tutorial #1  
Physics 205

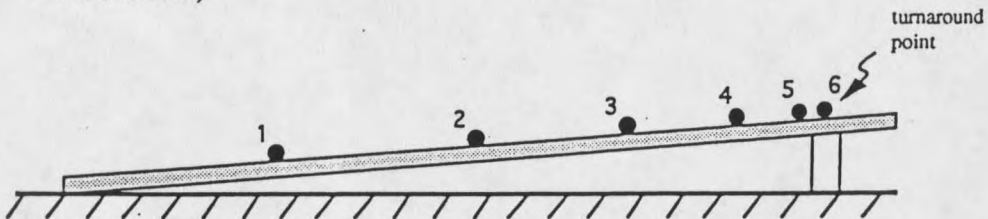
MOTION DIAGRAMS

Name \_\_\_\_\_

Work with your partners to answer the following questions. Draw all diagrams on the large sheet of paper provided, and discuss the answers before transferring your responses to this worksheet.

### I. Velocity diagrams

- A. The diagram below represents a strobe photograph of the motion of a ball as it rolls up a track. (In a strobe photograph, the position of the ball is shown at instants that are separated by equal time intervals.)



1. Draw vectors on your diagram that represent the instantaneous velocity of the ball at each of the labeled locations. If the velocity is zero at any point, indicate that explicitly. Explain why you drew the vectors as you did.

We will call diagrams like the one that you drew above *velocity diagrams*. Unless otherwise specified, a velocity diagram shows both the location and the velocity of an object at instants in time that are separated by equal time intervals.

2. Compare the velocities at points 1 and 2 by drawing the vectors that represent those velocities side-by-side. Label the vectors  $\vec{v}_1$  and  $\vec{v}_2$ , respectively.

Draw the vector that must be added to the velocity at the earlier time to equal the velocity at the later time. Label it  $\Delta\vec{v}$ . Why is the name "change in velocity" appropriate for this vector?

How does the *direction* of the change in velocity vector compare to the *direction* of the velocity? Would this comparison change if you were to select two *different* consecutive points (e.g., points 3 and 4) while the ball was moving up the track? Explain.

## Sample Physics 205 Tutorial

Tutorial #1  
Physics 205

### Motion Diagrams

3. Consider the *change in velocity vector* for two points on the diagram that are not consecutive, e.g., points 1 and 4.

Is the direction of the *change in velocity vector* different than it was for consecutive points? Explain.

Is the length of the *change in velocity vector* different than it was for consecutive points? If so, about how many times larger or smaller is it than the corresponding vector for consecutive points? Explain.

4. Use the definition of acceleration to draw a vector that represents the acceleration of the ball between points 1 and 2.

How is the direction of the *change in velocity vector* related to the direction of the *acceleration vector*? Explain.

Suppose someone were to draw an acceleration vector twice as long as the vector that you drew. Would that answer be wrong? Explain.

5. Does the acceleration change as the ball rolls up the incline? (i.e., Would the acceleration vector you obtain differ if you were to choose two different successive points on your diagram or if you were to choose two points that were not consecutive?) Explain your answer.

What does that imply about the change in velocity vector for different pairs of consecutive points?

6. Generalize the results above to answer the following questions:

What is the relationship between the *direction* of the acceleration and the *direction* of the velocity for an object which is slowing down? Explain.

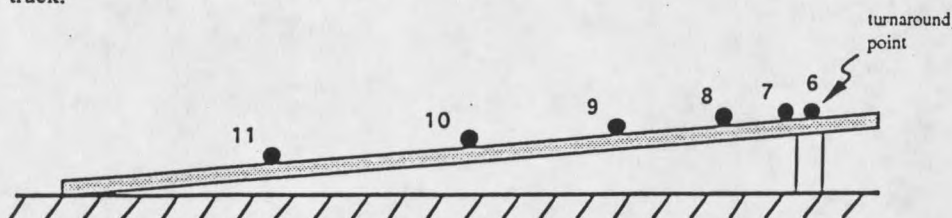
Describe the direction of the acceleration of a ball that is rolling up an incline.

## Sample Physics 205 Tutorial

Tutorial #1  
Physics 205

### Motion Diagrams

- B. The diagram below represents a strobe photograph of the motion of a ball as it rolls down the track.



- Choose two sequential times on your diagram and draw the velocity vectors of the ball corresponding to those times side-by-side. Determine the vector that must be added to the velocity at the earlier time to equal the velocity at the later time. Is the name "change in velocity" used in part A appropriate for this vector?

How does the *direction* of the change in velocity vector compare to the *direction* of the velocity in this case? Would this change if you were to compare the velocities for two other points during the time when the ball was speeding up? Explain.

- Draw a vector to represent the acceleration of the ball between the points you chose above.

How is the direction of the *change in velocity vector* related to the direction of the *acceleration vector*? Explain.

- Generalize the results above to answer the following questions:

What is the relationship between the *direction* of the acceleration and the *direction* of the velocity for an object that is speeding up? Explain.

Describe the direction of the acceleration of a ball that is rolling down an incline.

## Sample Physics 205 Tutorial

Tutorial #1  
Physics 205

### Motion Diagrams

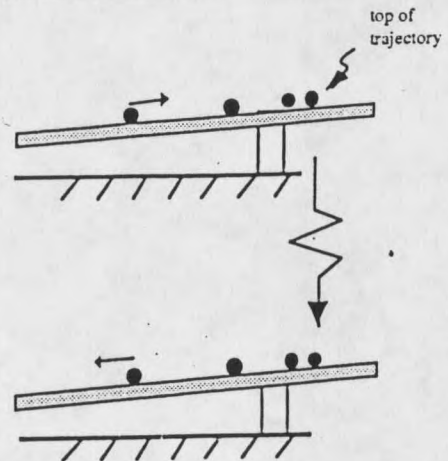
C. Complete the velocity diagram at right for the portion of the motion that includes the turnaround.

- Choose a point before the turnaround and another after. Draw the vector that must be added to the velocity at the earlier time to obtain the velocity at the later time.

Is the name "change in velocity" that you used in parts A and B also appropriate for this vector?

- Suppose that you had chosen the turnaround as one of your points.

Would this choice affect the direction of the *change in velocity vector*?



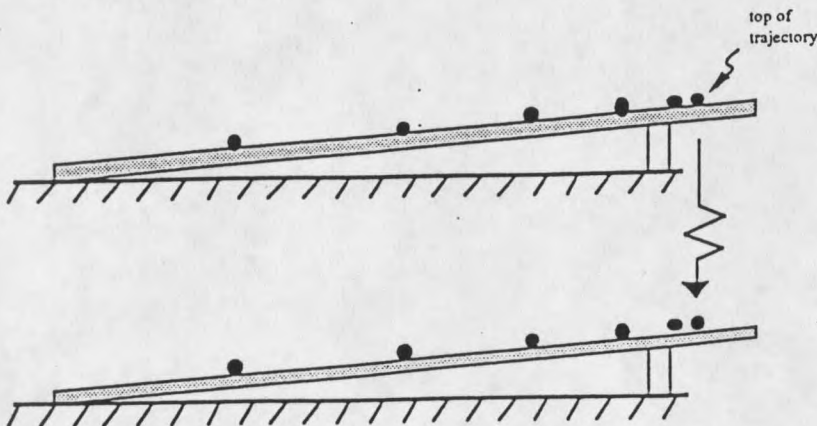
What is the *velocity* at the turnaround point? Explain.

What is the *acceleration* at the turnaround point? Explain.

## II. Acceleration diagrams

An *acceleration diagram* is similar to a velocity diagram, however, the vectors on an acceleration diagram represent the *acceleration* rather than the velocity of an object. For this class, acceleration vectors should not be included on a velocity diagram; a separate diagram should always be drawn.

Sketch an acceleration diagram for the entire motion of the ball rolling up, then down the incline.



**APPENDIX C**  
**RESEARCH TIME LINE**

RESEARCH TIME LINE

<u>DATE</u>	<u>RESEARCH PROCESS</u>	<u>PRODUCTS</u>
8/24 - 9/30/93	<i>Orienting Phase:</i> Attend TA Meetings Observe Tutorial Sessions Instruct weekly tutorial Informal Interviews	1. Participant Observation Journal 2. Fieldnotes
10/1 - 12/3/93	<i>Primary Data collection. &amp; analysis:</i> Participate in TA Training Instruct weekly tutorial Observe lectures Observe Tutorial Sessions Informal Interviews	1. Participation Observation Journal 2. Lecture Script Notes 3. Fieldnotes
11/5 - 11/22/93	Formal Interview #1 Teaching Assistants	1. Interview Audio-tape 2. Interview Notes 3. Interview Transcript 4. Participant Observ Journal
11/1 - 11/19/93	Tape Record Tutorial Sessions Observe tutorial sessions	1. Tutorial Audio-Tape 2. Fieldnotes 3. Participant Observ Journal
11/29 - 12/3/93	Videotape Tutorial Sessions	1. Tutorial Videotape 2. Fieldnotes 3. Participant Observ Journal
1/5 - 2/4/94	Formal Interview #2 Teaching Assistants	1. Interview transcript 2. Fieldnotes 3. Participant Observ Journal

Schedule of Observed Physics 205 Lectures

<u>Date</u>	<u>Lecture Section Number</u>	<u>Data</u>
10/4/93	1	Script Observation
10/6/93	1	Script Observation
10/13/93	2	Script Observation
10/27/93	1	Script Observation
11/3/93	2	Script Observation
11/12/93	2	Script Observation
11/17/93	1	Script Observation

**APPENDIX D**  
**DATA COLLECTION SCHEDULE**

DATA COLLECTION SCHEDULE

<u>Instructor</u>	<u>Date</u>	<u>Tutorial Section Number &amp; Data</u>
BEN	9 /23/93	15 Script Observation
	10/28/93	15 Audio Tape & Script Observation
	11/ 4/93	15 Audio Tape #1 & Script Observation
	11/18/93	15 Audio Tape #2 & Script Observation
	11/22/93	Formal Interview #1
	12/93/93	15 Videotape & Script Observation
	2 / 3/94	Formal Interview #2
UVE	9 /28/93	5 Script Observation
	10/26/93	5 Script Observation
	11/ 2/93	5 Audio Tape #1 & Script Observation
	11/ 5/93	Formal Interview #1
	11/16/93	5 Audio Tape #2 & Script Observation
	1-1/30/93	9 Videotape Tape & Script Observation
	2 / 2/94	Formal Interview #2
DAVID	9 /29/93	4 Script Observation
	10/27/93	8 Script Observation
	11/ 5/93	20 Audio Tape #1 & Script Observation
	11/19/93	20 Audio Tape #2 & Script Observation
	11/22/93	Formal Interview #1
	12/ 2/93	13 Videotape & Script Observation
	2 / 2/94	Formal Interview #2
TOM	9 /23/93	17 Script Observation
	10/26/93	4 Script Observation
	11/ 2/93	4 Audio Tape #1 & Script Observation
	11/10/93	Formal Interview
	11/16/93	4 Audio Tape #2 & Script Observation
	11/30/93	4 Videotape & Script Observation
	2 / 3/ 94	Formal Interview #2
SUYUAN	9 /29/93	9 Script Observation
	10/29/93	19 Script Observation
	11/ 5/93	19 Audio Tape #1 & Script Observation
	11/12/93	Formal Interview # 1
	11/19/93	19 Audio Tape #2 & Script Observation
	12/ 1/93	10 Videotape & Script Observation
	1 /31/94	Formal Interview #2

**APPENDIX E**

**Interview Format & Questions**

**Physics 205 Graduate Teaching Assistants**

Interview Format & Questions  
for Physics 205 Graduate Teaching Assistants

OPENING STATEMENT

I'd like to tape record what you have to say so that I don't miss any of it. I don't want to take the chance or relying on my notes and "thereby miss something that you say or inadvertently change your words somehow. So, if you don't mind, I'd like very much to use the recorder. If at any time during the interview you would like to turn the tape recorder off, all you have to do is press this button on the microphone, and the recorder will stop." (Patton, 1980, p. 247)

As you know, I'm interested in the implementation of tutorials in physics 205. Naturally, your role as a tutorial instructor is very important to the process. I'm interested in what the tutorial instructor experience has been like for you.

Remember that what you say is confidential, while your comments will contribute to the knowledge base of my study, you would never be personally identified with the information you provide. My hope is that you will be completely candid in your responses, so that I might create an accurate picture of the role of graduate teaching assistants. I will provide you with a copy of the tape and the summary of my notes from this interview. If you want to add or delete information later, or clarify any responses, I encourage you to do that.

Remember our agreement is that you can end this interview at any time. Do you have any questions about this study before we begin?

(Use Name ), if any of my questions aren't clear to you or you have any questions as we go along, please don't hesitate to stop and ask for clarification.

QUESTIONS

If you were talking to someone, who didn't know anything about the physics tutorial, how would you explain exactly what you do as a tutorial instructor?

Can you describe what your thoughts were like when you learned that you would not be a laboratory instructor for Physics 205, but that you would be a Tutorial instructor?

What it is the experience like for you as a tutorial instructor? Do you feel anxious, happy, afraid, intimidated, confident ...

When you're walking around the tutorial room, what do you see? Describe what students do in the tutorial sessions?

What would someone see students doing if they visited one of your tutorial sessions.

Describe the types of science instruction that you have experienced as a high school and college student?

What is your preferred, past or present, science learning experience? If you have a favorite way to learn science what would it be?

How do you think people learn science best?

What do you believe is "working" in your tutorial sessions? (What are the strengths of the tutorial process?)

What's not working in your tutorial sessions? (What weaknesses do you see in the tutorial Process or in your ability to carry out the model as a beginning instructor.)

What do you like most about being a tutorial instructor?

What do you like least about being a tutorial instructor?

What is your opinion of the TA Tutorial Training Sessions?

Suppose that you were in charge of training tutorial instructors, what would you like to see happen to assist graduate teaching assistants?

What have you learned from the experience of being a tutorial instructor? (presupposes some learning)

Tell me about your experience as a graduate student?

What led you to MSU and physics graduate school?

What degree program are you in?

Where are you in the program?

Do you know yet what you might do with your education?

When I first started teaching, I had a friend who liked to listen to all my teacher stories, I was so amazed by some of the things that would happen in the classroom and she encouraged me to talk about them. Can you tell me any stories about your experiences with students in physics 205?

NOTE: The plan was to keep the interviews conversational and to have the informant speak candidly about experiences, beliefs and feelings.

Conversational probes were used as required. They consist of *detail-oriented* questions. These questions are designed to fill in the blank spaces of a response (Patton, 1980, p. 238). Who, where, what, when and how questions elicit particular details:

What was your involvement in that situation?

How did that come about?

Where were you during that time?

When did that happen?

Elaboration probes were used by the interviewer to keep the respondent talking more about a subject. Patton (1980, p. 239) suggests strategic head-nodding and verbal use of "uh-huh" may be used to communicate interest in having the interviewee elaborate. These strategies are aimed at communicating that the interviewer is listening and wants to go on listening, but are intended to be neutral. It is not the intent of the interviewer to indicate any agreement or disagreement with the informant. Direct statements will also be used:

Would you elaborate on that?

Could you say more about that?

That's helpful. I'd appreciate it if you could give me more detail?

I'm beginning to get the picture. (Implies that I don't have the full picture yet, so please keep talking)

I think I'm beginning to understand.

Let me make sure I've got that down exactly what you said, then I'd like to ask you to say more about that.

Clarification probes were used to indicate that more information was needed, a restatement of answer or more detail. These probes were to appear natural and suggest that it is the interviewer failure to understand, rather than any fault of the person being interviewed.

I'm not sure I understand what you mean by that. Could you elaborate?

You said that the program was "....." Help me to understand what you mean by "....."?

I'm not sure I understand exactly what you mean?

I didn't quite catch your full meaning. Would you run that by me again.

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