THE EFFECTS OF A CONSTRUCTIVIST LEARNING ENVIRONMENT ON STUDENT COGNITION OF MECHANICS AND ATTITUDE TOWARD SCIENCE: A CASE STUDY

by

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The purpose of this project was to examine the effects of a constructivist learning environment on student cognition of mechanics and attitude toward science compared to students enrolled in a traditional lecture course. The constructivist course utilized cooperative grouping and microcomputer-based labs with very little lecture to teach mechanics. Enrollment in the course was limited to women and minorities.

Case study methodology was used to collect and analyze the data. The data was both qualitative and quantitative in nature. The qualitative data consisted of formal interviews, copies of course work, a participant observation journal, and video tape of class sessions. Quantitative data consisted of student test scores from a cognitive exam, *The Mechanics Baseline Test* and an attitude survey, Attitude Toward Science in School Assessment.

A t test procedure showed that quantitatively there were no significant differences in the two groups. Qualitatively, students said they enjoyed science more if the constructivist strategies; instructor interaction, hands-on activities, and applications to everyday life, were used. Women in the courses said they felt more confident with their career choice because they

were successful in their physics course. Even though students in the constructivist course had a median SAT score that was 270 points below the lecture section, they performed just as well on *The Mechanics Baseline Test*. Lastly, it was determined from qualitative data that students must be able to understand graphs and diagrams to be successful in science courses.

To Jimmy, Harrison, and Meghan.
We Did It.

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CHAPTER I

STATEMENT OF THE RESEARCH

Introduction

Despite efforts by many educational groups, women and minorities remain underrepresented in science and science related careers (Hill et al., 1990). In an effort to increase the number of women and minorities entering engineering and other science-related careers, the American Association for the Advancement of Science (1990) has called for science education reform such that the learning of science content is more meaningful to these groups. AAAS (1990) implemented Project 2061 in an effort to initiate reform in science education. According to AAAS the major intent of this project is to create an educational system that would; a) maximize the variety of career options and employment opportunities for all graduates, b) enable all Americans to make sound emotional and political decisions involving science and technology, c) engage students in such a way that students and citizens can follow science with an interest and relate science to their everyday lives, and d) show students that science applies to our everyday lives. AAAS believes that these goals cannot be met unless a broader, more general goal, is first addressed. AAAS states that the general population must view science more favorably and more intelligently.

To accomplish the general goal that the general population view science more favorably and more intelligently, science educators are encouraged to use instructional strategies that allow meaningful learning to take place (Rutherford & Ahlgren, 1990). The AAAS (1990) encourages educators to provide students with experiences much like the work of scientists in the field. Brown, Collins, and Duguid (1989) also believe that students should be given the opportunity to participate in authentic practices of scientists in the field and furthermore that students should use the tools of scientists to solve real world problems. They call this practice situated cognition.

Meaningful learning can be defined as the ability to apply science concepts to everyday situations. Meaningful learning and understanding of science concepts can occur when students are given opportunities in which they are able to construct their own knowledge (Rutherford & Ahlgren, 1990). Situated cognition provides students with the opportunity to construct their own knowledge (AAAS, 1990; Brown et al., 1989; Pintrich et al., 1993; Duckworth, 1986; Roth, 1993).

Physics educators have been particularly interested in using authentic practices of scientists to facilitate student cognition of physics concepts (Arons, 1990; McDermott, 1984). If students have a good understanding of physics concepts they will be able to view science more intelligently. The Washington Physics Education group supports restructuring the traditional methods of teaching physics to include authentic practices of physicists and other instructional strategies that facilitate better understanding of physical phenomena (McDermott, 1984; Rosenquest & McDermott, 1987). Other instructional strategies that have been identified as providing students with the opportunity to construct their own knowledge include but are not limited to: a) utilizing the environment for points of curiosity; b) asking thoughtful open-ended questions; c) employing problem solving strategies; d) collecting and organizing data; e) experimenting with materials; f) designing and using models to elicit discussions; g) using student responses to drive the lesson and applying knowledge and skills (Yager, 1991). Use of microcomputer-based laboratories (MBL) has also proven to be especially successful in allowing students to construct their own knowledge (Thorton, 1989). These strategies are called constructivist strategies (Yager, 1991). Using these strategies and allowing students to construct their own knowledge is part of a learning theory called constructivism. Constructivists believe that students actively construct their own knowledge and that this construction is an adaptive process (Glaserfeld, 1987). Learners construct their knowledge through interactions with and in the environment. They can do this in the physical environment by manipulating the tools of scientists or in the social environment by working in a peer group (Wheatley, 1991).

Physicists at the University of North Carolina at Greensboro and Bennett College, both located in Greensboro, North Carolina, now offer an introductory physics course that utilizes these strategies. Their goal is to facilitate better understanding of physics concepts and facilitate more positive attitudes toward science. In other words, their goal is for students to view science more intelligently and more favorably. The course is titled Physics and the 3 Rs. The aim of the course is to: a) recruit more women and minorities to enroll in introductory physics; b) restructure the traditional method of teaching to include constructivist practices; and c) retain women and minorities in science and science related courses (Meisner & Ponting, 1991).

Restructuring the typical pedagogy involves leading students to become *doers* of science versus observers of science. (Meisner & Ponting, 1991). Typically, an introductory course in physics is offered as a lecture with a separate laboratory. The typical lecture involves the professor solving problems at a board in front of the lecture hall and/or conducting demonstrations. The typical laboratory is a verification lab where the students complete step by step procedures to 'verify' a known outcome. In contrast, the 3 Rs course uses constructivism as the pedagogical basis, i.e., the students are actively engaged in the learning process by interacting in the physical and social environment. Research has shown that by providing students with the opportunity to participate in authentic tasks (physical environment) in cooperative groups (social environment) they become more efficient in constructing knowledge regarding physical phenomena. Students can do this because they are solving real problems in which the outcome is not a predetermined answer.

Changing pedagogical methods would also help achieve the second goal of AAAS - that students view science more favorably. Students who view science more favorably have a more positive attitude toward science. Attitude can greatly influence career choice (Koballa & Crawley, 1986; Hill et al., 1990) and learning (Koballa & Crawley, 1986; Pintrich et al., 1993).

Not only has method of pedagogy been identified as affecting cognition and attitude toward science, but classroom factors have also been identified as affecting students' attitudes toward and how well students cognitively understand concepts presented in courses (Arons, 1985; Arons & Karplus, 1987; Cannon & Simpson, 1985, Dykstra et al., 1992; Krynowski, 1988; Lawrenz, 1975; Lawrenz, 1976; Myers & Foutz, 1992; Welch, 1976). These factors include single sex classes, opportunity to experience phenomena contrary to student beliefs, a noncompetitive environment (Stipek, 1993), evaluation based on improvement, mistakes viewed as positive, and use of metacognitive strategies (Pintrich et al., 1993).

Purpose of the Study

The purpose of this study was to examine how restructuring of the typical pedagogy in an introductory physics class affected student cognition of mechanics and student attitudes toward science.

Hypotheses

1. Students enrolled in the 3 Rs course will have a greater understanding of physics concepts related to mechanics than students enrolled in a traditional physics course.

2. Students enrolled in the 3 Rs course will exhibit more positive attitudes toward science than students enrolled in a traditional physics course.

Limitations

Participants in this study were limited to those students enrolled in two sections of Physics 101 in the Fall Semester of 1994 at The University of North Carolina at Greensboro. These were two nonequivalent groups with different instructors. Participation in the study was strictly voluntary.

The study was also limited by the use of case study methodology. Use of case study methodology has the potential to present the biased interpretations of the researcher. Since the researcher in this case study was also a participant observer there were other unique limitations that also existed. According to Yin (1985), a participant observer can be limited by her potential to be biased to the case and as a participant she often must assume roles that are contrary to good scientific practice. He also states that the participant observer is more likely to follow a commonly known phenomenon and become a supporter of the group. In addition, Yin has stated that the role of participant observer is often limited by the amount of time she has to be an observer by her role in the case. These factors limit the participant observer because she may not have sufficient time or raise questions about events from different perspectives.

Yin believes that these limitations can be balanced by the advantages the role of participant observation can present. These include unlimited access to the group, the ability to perceive reality from inside the group, and the researcher's ability to manipulate the situation. These manipulations may not be as precise as those in a scientific experiment but they can provide many opportunities for collecting data.

Significance of the Study

Scientific literacy and equal opportunity to maximize the variety of career options and employment opportunities for all graduates has become a major goal in science education. A scientifically literate person has a positive attitude toward science. A positive attitude is an important part of scientific literacy because of its potential to affect learning, career choice, and the ability to deal with technological change. Students who are provided with the opportunity to construct their own knowledge have a better understanding of science concepts. Students who are provided with the opportunity to learn physics in a constructivist course should have higher cognitive knowledge and more positive attitudes toward science, both of which are an important part of scientific literacy.

Summary

Project 2061 was implemented in 1985 as a means of addressing the shortage of scientists and engineers. AAAS believes that this goal cannot be obtained unless the general population views science more favorably and more intelligently. AAAS has emphasized that in order for students to be able to view science more favorably and more intelligently meaningful learning must take place in science classrooms. Cognitive research implies that individuals must construct their own knowledge in order for meaningful learning to occur. The classroom environment and choice of tasks can provide students with the opportunity to construct their own knowledge and can encourage more positive attitudes toward science. The 3 Rs course strives to implement practices identified in the research as allowing students to effectively construct their own knowledge. The purpose of this study was to examine how the constructivist learning environment that existed in the 3 Rs classroom affected student cognition of mechanics and attitude toward science.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

Introduction

Student understanding of physics concepts is necessary to meet the broad general goal identified by AAAS that students view science more intelligently. Changing student attitude toward science is important to the AAAS goal that view science more favorably. Therefore, it is important to review the science education literature to identify studies that have examined cognition of physics concepts and student attitude toward science as it relates to constructivism. There exists a large body of studies in the science education literature that examine constructivist pedagogy (Appleton, 1993; Ebenezer & Zoller, 1993; Glaserfeld, 1987; Glasson & Lalik, 1993; Wheatley, 1991) and student cognition (Appleton, 1993; Fredrickson, 1984; Piaget, 1964; Pressley & McCormick, 1994; Roth, 1993; Roth , 1994). Other studies report the effects of instruction and learning environment on attitude toward science (Ajerwole, 1992; Glasson & Lalik, 1993; Germann, 1988; Gogolin & Swartz, 1992; Lin & Crawley, 1985; Matthews, 1990; Myers & Fouts, 1992; Saunders & Young, 1985). The results of a literature review are presented in this section. An examination of the literature on constructivism and cognition of physics concepts is followed by a review of the literature on attitude toward science.

Constructivism/Cognition

Lecture, the typical method of teaching, has failed to produce a population of scientifically literate individuals and has failed to recruit women and minorities into the sciences (Rutherford & Ahlgren, 1990). Science educators are calling for a reform in the current methods of teaching (Arons, 1990; McDermott, 1984; Roth, 1993).

Physics educators have long been interested in how students learn and how physics educators can facilitate better understanding of physics concepts (Roth, 1993; Fischer & Von Aufschnaiter, 1993). Educators have suggested that this can be accomplished when students *do* science, not merely hear about science (Duckworth, 1989; Meisner & Ponting, 1991). Research also indicates that empirical and phenomenological experiences are important in learning physics concepts. (Arons, 1990; McDermott, 1984). Constructivists also support this premise (Roth, 1993; Roth, 1994).

Constructivism as a theory examines knowledge structures. There are two basic tenets of constructivism; 1) that students actively construct their own knowledge and 2) that this construction of knowledge, learning, is an adaptive process (Roth, 1993). "Knowledge", Piaget has stated, "is not a copy of reality" (Piaget, 1964, p 177). Learning is personal and unique to each individual (Wheatley, 1991). In order to learn, individuals construct meaning from interacting with the physical and social environment. (Glaserfeld, 1987). Learners construct and reconstruct their cognitive frameworks based on these interactions (Pulaski, 1971).

Conceptual Restructuring

Piaget (1964) theorized that all information must be organized by the learner. This is accomplished through assimilation. Information is placed into the appropriate scheme (assimilated) based on the way the child or adult perceives the world and his/her current knowledge (Pulaski, 1971). If information fits into no existing schema, then the learner must change or accommodate his/her existing schema in order to place the information into a conceptual framework (Demby, 1991). The learner accommodates or changes his/her view of reality after obtaining new knowledge (Miller, 1993) thus restructuring his or her conceptual framework.

Appleton (1993) has proposed a theoretical basis for how this restructuring occurs. (See Figure 1). Appleton proposed that the learner is initially in a state of conceptual equilibrium. Piaget believed that individuals were driven by the need to maintain their conceptual equilibrium (Piaget, 1964). When the learner experiences a new encounter, a filter is used to sort through recall in a search for an identical fit of the encounter to an existing idea in the learner's conceptual framework (Appleton, 1993). This occurs when the short-term memory receives information from the sensory buffer (Miller, 1993). The sensory buffer filters sensory perception from the sense

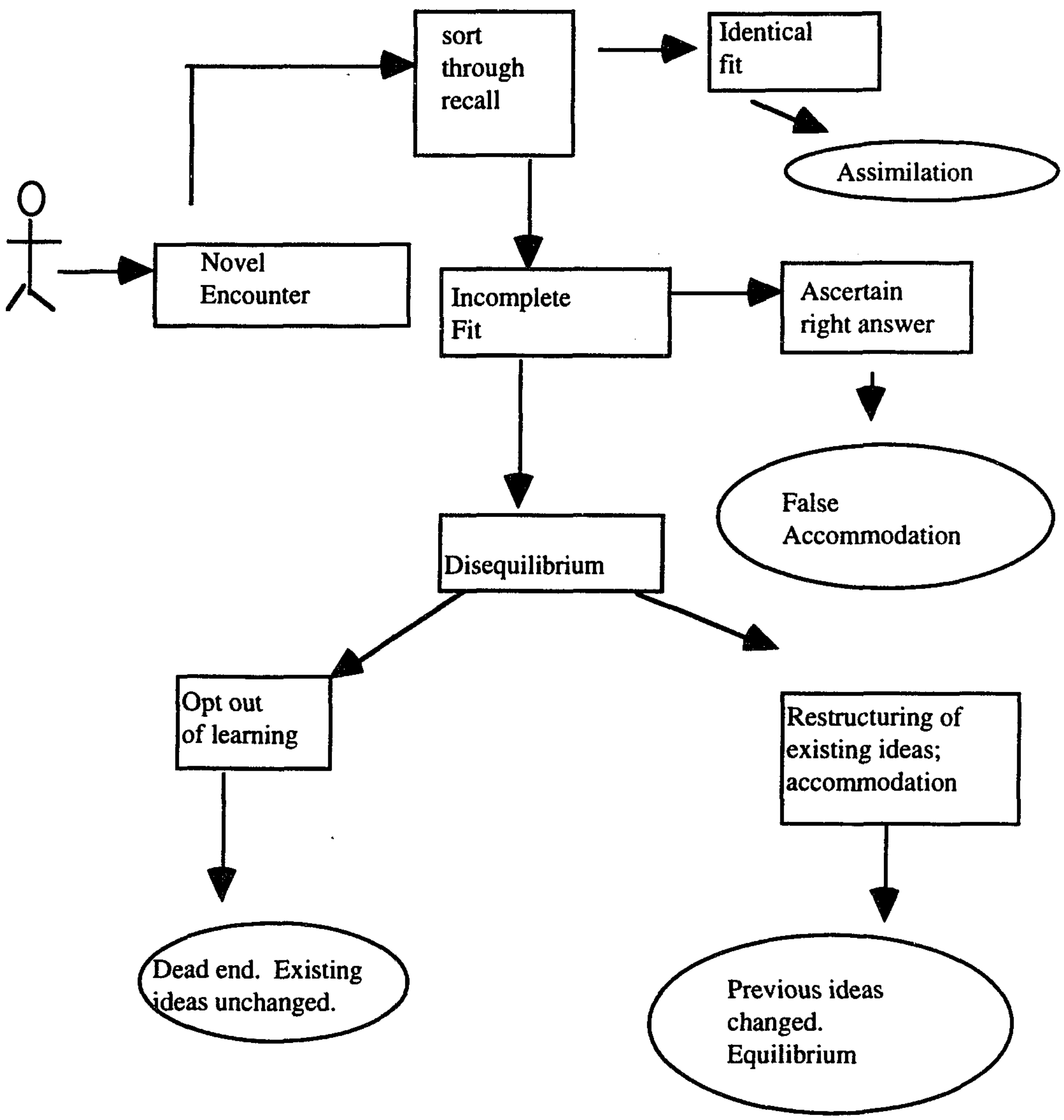


Figure 1

organs. Stimuli from the environment are detected by the sense organs and are transferred through nerve impulses to the sensory registers in the brain (Campbell, 1993). These registers act as a buffer or filter and transfer information to the short term or working memory (Pressley & McCormick, 1994). A search is then conducted of the long term memory of the declarative and procedural knowledge frameworks to identify information that is similar to the current stimuli (Driscoll, 1994). If the search identifies a "fit" then the stimuli are encoded and stored in the long term memory within the framework in which the scheme or production was found (Fredrickson, 1984). At this point, assimilation of the idea has occurred and the learner exits the cognitive exercise. The current idea is reinforced regardless of whether the idea is or is not correct (Appleton, 1993).

If a search of the conceptual framework identifies no fit, the learner will check the incorrect idea. If the learner cannot place the idea into an existing conceptual framework, uneasiness and disequilibrium occur (Piaget, 1964). Some learners may attempt to ascertain the right answer (Appleton, 1993). This scenario generally occurs in school situations where students learn the right answers for the test (Appleton, 1993; Dykstra et al., 1992). This results in existing ideas remaining unchanged, with a new set of ideas being filed for school situations (Appleton, 1993; Dykstra et al., 1992). A second scenario that may occur when the identical fit is not found is for the learner to opt out of learning (Appleton, 1993).

The scenario that teachers wish for students is the third scenario (Appleton, 1993), in which restructuring of existing conceptual frameworks and accommodation take place. In this scenario a complete fit occurs and learning adaptation takes place. Previous ideas held by the learner are changed and again the learner is in cognitive equilibrium. Accommodation is the adaptation of the learner's existing conceptual framework to make the new information fit into the learner's schema thus placing the learner in conceptual equilibrium (Piaget, 1964).

Teachers can facilitate the path learners take in Appleton's model (Appleton, 1993). Many researchers (Duckworth, 1989; Ebenezer & Zoller, 1993; Glasson & Lalik, 1993; Yager, 1991) have stressed the importance of the role of the teacher as a facilitator of instruction and conceptual bridge builder. Research indicates that student cognition increases when the instructor assumes the role of facilitator (Andrews & Meisner, 1994). By questioning students, the teacher can identify the student's misconceptions and the teacher can guide the student to conceptual equilibrium (Appleton, 1993).

Teachers can guide the learner to conceptual equilibrium by challenging conceptions students currently hold. Several methods or strategies have been identified as having an effect on identification of misconceptions and facilitating conceptual restructuring or conceptual change. Dykstra et. al., (1992) has stated that physics instruction should begin with students' beliefs about the world. Dykstra and his colleagues believe that the general strategy that should be used to lead students to conceptual change is to present students with situations that are contrary to their beliefs. Students must be allowed to make predictions about physical phenomena. Instructors, they have stated,

should find phenomena that are easy to produce and whose outcome will differ in some way with students' predictions. Furthermore, students should be allowed to discuss how their predictions were different from their observations and why the phenomena occurred as it did.

Teachers should serve as the conceptual bridge builder between what the students have observed and the theory behind the observation (Glasson & Lalik, 1993). Teachers should question their students (Duckworth, 1989) and allow their students to work in cooperative pairs or small groups (Wheatley, 1991). Working in cooperative groups allows students to engage in dialogue. By having students verbalize their thoughts, the teacher and the student can identify misconceptions and the necessary restructuring of cognitive frameworks can occur.

The Constructivist Model

Allowing students to interact with objects and with one another to construct meaning is part of a learning theory called the Constructivist Learning Model (Yager, 1991) or constructivism. Based on cognitive science research, this model places emphasis on the learner. Learning is an active and adaptive process that takes place within the learner as indicated by Appleton's model. From this perspective, learning outcomes are an interactive result of the information or stimuli a learner receives and how he/she processes that information based on existing ideas and background knowledge. These interactions take place in both the social and physical environments (Glaserfeld, 1987).

The social environment involves people and their interactions through language and communication (Yager, 1991). Student understanding evolves as they negotiate meaning through testing their ideas in relation to the ideas held by their peers (Bayer, 1990). Vygotsky, a contextualist (Miller, 1993), emphasized the importance of language and adult-child interaction in cognitive development (Glasson & Lalik, 1992). Tudge (1993) stated that as a contextualist Vygotsky was interested in the context of development. Tudge believes that this does mean not that students learn in different contextual situations, but he believes that there are three contextual levels; a) individual factors, (temperament, motivation, age, intelligence, and gender); b) sociocultural/historical (race and or background) experiences; and 3) interpersonal experiences, (which include family, peers, school, and church). These three factors are interwoven into a person's cognitive and linguistic development. Development occurs externally before it can occur internally, as one attempts to make sense of what is being said, he/she changes his/her thinking.

Those who aspire to this sociocultural model believe that students move from external control to internal control (Howe & Jones, 1993). Teachers can facilitate cognitive growth by modeling, using peer tutoring, and cooperative learning (Miller, 1993).

Interactions in the physical environment take place with objects. Piaget (1964) has stated that in order to know an object one must act on it. This is important to science education. As students act on tools and objects in the manner that scientists do, they can develop understanding. It is the teacher's task to present situations in class that draw upon this theory (Yager, 1991). Teachers should provide the opportunity for students to interact in the physical and social environment and should place more emphasis on how students view a problem rather than whether they arrive at the right answer (Yager, 1991). They can do this by using constructivist strategies for teaching. Yager (1991) believes that constructivist strategies invite students to learn, explore, propose explanations and solutions, and take action. Teachers can invite students to learn by using the environment for points of curiosity and by asking thoughtful open-ended questions. Students can explore by employing problem-solving strategies, collecting and organizing data, and experimenting with materials. Students can explain phenomena by designing models. Students can take action by applying knowledge and skills. An example of a constructivist practice is the use of microcomputer-based laboratories (MBL). MBL has proven especially successful in allowing students to construct their own knowledge and to identify discrepancies in their existing frameworks (Thorton, 1989).

Applications to Physics

Use of MBL in the classroom creates an environment that simulates the practices of scientists in the field (Thorton, 1989). In a study of students enrolled in an introductory algebra-based physics course at the University of Oregon, researchers found that students in a special section that utilized MBL to explore heat and temperature significantly lowered their pretest error rate on the posttest (Thorton & Sokoloff, 1989). Rosenquest and McDermott (1987) found that when students in an introductory course were exposed to instruction that emphasized the application of kinematics concepts to actual motion, as MBL allows, they achieved at a level of understanding that matched students with stronger backgrounds in a traditional course.

As has already been stated previously, students' conceptual frameworks often contain misconceptions based on their experiences and interactions with the physical world. Such misconceptions can interfere with understanding physics concepts (Arons, 1990; Driver & Easley, 1978; Driver & Erickson, 1983; Dykstra et.al., 1992; McCloskey, 1983; McDermott, 1984). These misconceptions are present at all levels of study. For example, researchers in Norway found that even physics graduate students have misconceptions of physical phenomena (Sjøberg & Lie, 1987).

Many students have difficulty understanding certain concepts of mechanics (McDermott, 1984). Minstrell (1982) found that students could not conceptualize normal forces. Minstrell demonstrated that when books were piled on a student's hands the student had to apply an equal and opposite force to continue to hold the books. Students could understand that a living thing (the person) would have to apply an equal and opposite force to hold the books, but could not understand that a table holding books must also exert an equal and opposite force on the books (or the books would fall through the table to the floor).

Students also have misconceptions about free fall. Champagne et al., (1980) found that even though 'bright' students could answer certain questions, their answers were based on incorrect assumptions. Students were successful in predicting time of fall for certain objects. However, these predictions were based on the incorrect assumption that velocity and acceleration could be equated with mass and weight. From this incorrect assumption, the students concluded that force was proportional to speed. This study caused the researchers to realize that misconceptions could be hidden behind correct answers.

The realization that students hold many misconceptions and that these misconceptions were retained throughout their studies at universities led science educators to evaluate the traditional method of pedagogy (Dykstra et al., 1992). Many physicists advocate reform away from lecture toward a more constructivist method of teaching that would allow instructors to identify misconceptions and allow students to be active participants in the learning process (Arons, 1985; Arons, 1990; Brown, 1992; Dykstra et al., 1992; McDermott, 1984; Thorton, 1989; Thorton & Sokoloff, 1990).

Constructivist Studies

Studies that examined the effect of using a constructivist method of teaching in physics have been conducted by Roth (1993, 1994) and by Fischer and Von Aufschnaiter (1993). Roth (1993) found that when students were able to frame their own exploratory questions (using student responses to drive the lesson) and when the teacher served as the conceptual bridge builder by asking thoughtful open-ended questions to guide student thinking, students were able to correctly construct their own knowledge. Roth (1994) found that when students worked in cooperative problem-solving groups, they began to approach tasks more like practicing scientists. Fischer and Von Aufschnaiter (1993) found that students enrolled in a constructivist physics course changed their language as they worked in the physical and social environment. The meaning of words changed for students during the learning process and words for new objects were used only after meaning was constructed.

Few studies are available in the literature that examine constructivist methods of teaching, although many articles exist that explore how constructivist theory applies to the science classroom (Appleton, 1993; Wheatley, 1991, Yager, 1991). A large portion of those studies have been presented in this chapter. Research conducted by Ebenezer & Zoller (1993) indicates that students would like science better if teachers were to adopt constructivist methods of teaching. Ebenezer and Zoller also found that students believed they would like science better, i.e., have more positive attitudes toward science, if their science lessons applied to local situations and if instruction was related to everyday life. Practices that were reported to have a negative affect on student attitudes include extensive note-taking and memorization. Thus the literature supports the view that use of constructivist strategies can influence student attitudes.

Attitude Studies

Just as Appleton's model can be used to explain how students learn and how teachers can facilitate the learning process, Appleton's model also can serve as a model for facilitating positive attitudes toward science. Background knowledge is important to learning new concepts. Beliefs and values are important in forming attitudes (Koballa, 1986; Shrigley & Koballa, 1992). Misconceptions can hinder learning. Certain beliefs and values have been shown to hinder change in attitude (Koballa, 1986). Science educators are interested in attitudes because attitudes are correlated with (Shrigley, 1989) and are antecedents to behavior (Koballa, 1986). These experts also believe that we must distinguish between beliefs, attitudes and behaviors. Koballa (1988) suggested that attitudes are formed based on a person's beliefs, with regard to right or wrong. Shrigley, Koballa, and Simpson (1988) contended that science educators should not confuse attitudes, beliefs, and values. Beliefs are cognitive and values are broader and culturally bound. The desired outcome is the behavior (Koballa, 1986; Shrigley, 1989; Shrigley & Koballa, 1992).

Because beliefs are cognitive, teachers can guide students to change beliefs just as they can lead students to conceptual change in physics cognition. Student beliefs must be challenged just as misconceptions must be challenged. Andrews and Matthews (1993) found that student attitudes toward scientists showed significant positive changes after their stereotypic view of scientists had been challenged. Educators can work within this framework to change negative attitudes toward science. If a student believes that science class is uninteresting, his/her beliefs can be challenged by implementing practices that have been demonstrated to improve student interest in science. The literature contains many studies that examine how various teaching practices affect student attitudes toward science.

Teaching Practices

Glasson & Lalik (1993) found that students believed they would like science better if the lessons applied to local situations and if instruction was related to everyday life. Students disliked classes that included extensive note taking and classes that required memorization. Gogolin and Swartz (1992) found that nonscience majors' attitudes toward science improved after participation in an anatomy and physiology course designed specifically for nonmajors. The course emphasized applications for daily living, was human in its orientation, and used hands-on activities. Most students in the course indicated they had never before been exposed to hands-on science.

Additional studies indicate that students like science more if they are able to participate in hands-on activities. For example, Ajerwole (1992) found that students exhibited more positive attitudes toward science when discovery learning was used. Discovery learning is decidedly constructivist. Recall that constructivism supports active student involvement in the learning process. Students are able to construct their own knowledge when they actually participate in activities. Discovery learning allows students to construct knowledge, or discover concepts through exploration.

Students in the Glasson and Lalik (1993) study indicated they would like science better if it applied to real life. Matthews (1990) also found this to be true in a study of the effects of teaching science to Native Americans using hands-on, culturally relevant materials. Members of certain tribes had significantly more positive attitudes after exposure to these materials.

Physical Environment

Constructivists also believe that the physical environment is important to the student construction of knowledge. Saunders and Young (1985) showed how using living materials in science instruction affected student's attitudes toward science. They reported significant differences in attitude toward science in biology classrooms that used live materials. They suggested that the presence of the live materials aroused students' interest and curiosity and thus stimulated learning.

Lin and Crawley (1985) also studied the effects of the physical environment on student attitudes toward science. They found that students in metropolitan school environments had more positive attitudes toward the social benefits of science, the use of scientific inquiry, and the attributes of scientists. They noted that students in metropolitan areas were more likely to participate in science-related activities than students in rural areas. No significant differences were found between metropolitan school student attitudes and rural school toward student attitudes with regard to the enjoyment of science lessons, normality of science, or career interest.

Social Environment

The social environment also influences student attitudes toward science. Germann (1988) found that the social interaction between the learner, teacher, and the curriculum had significant positive effects on student attitudes toward science. Students in classrooms with high social interaction, laboratory practices, a supportive teacher, and better instructional methods, had more positive attitudes toward science. Myers and Fouts (1992) also found that students in classroom environments which had high levels of involvement (social interaction) had significantly more positive attitudes toward science. They also found that working in cooperative groups affected student attitudes toward science. Other variables identified as affecting attitude were high teacher support, high order and organization, and use of innovative teaching methods.

Teacher support also has been identified by Gagné (1985) as important in the acquisition of attitudes. The teacher must establish an expectancy of success if students are to acquire positive attitudes. Schibeci and Riley (1986) and Haladyna, Olsen, and Shaughnessy (1983) have identified teacher support as a major contributor to positive attitude acquisition. They found that teacher enthusiasm contributes to positive attitudes.

Haladyna, Olsen, and Shaughnessy (1983) identified teacher quality as the major contributor in the variance of student attitude toward science. Koballa and Rice (1985) have even listed six teacher behaviors that can lead to the positive acquisition of attitudes. These include: a) know the content; b) be aware of the student's home environment and use this environment when possible; c) know the students and their needs; d) find out what attitudes and skills students already possess; e) challenge students existing ideas; and f) make students doers of science rather than merely talking about doing science. Mason and Kyle (1988) found that when teachers participated in a program to stimulate a gender-free learning environment their students demonstrated more positive attitudes toward science. The teacher was shown to be an influencing factor in affecting student attitudes.

Other practices that teachers can use to improve attitudes include providing opportunities for success (Gagné 1985), arranging for students to express their choice of personal action, providing feedback for successful performances (Driscoll, 1994), providing a positive learning environment (Germann, 1988), viewing mistakes as positive and part of the learning process, making evaluation in the course improvement-based, using metacognitive strategies (Pintrich et al., 1993), and providing a noncompetitive environment (Stipek, 1993).

As previously stated, attitude is important because it is an antecedent to behavior and has been identified as an important factor in career choice (AAAS, 1990; Hill et al., 1990; Koballa & Crawley, 1986; Rutherford & Ahlgren, 1990). One goal of the 3 Rs course is to foster more positive attitudes in science so that women and minorities might choose science as a career. Science typically is viewed as a male profession (Hill et al., 1990). The 3 Rs course intends to foster positive attitudes by providing students with a learning environment that includes factors mentioned in the previous sections. This environment theoretically will challenge the belief held by many women and minorities that they can not be successful in physics. By changing their belief, preconceived notions and existing negative attitude toward science can be negated. Hill et al., (1990) identified interest in a subject (the antecedent) as a major factor in choosing a career (the behavior). Other researchers have found that students who like science (the antecedent) are more likely to pursue science as a career (the behavior) (Entwistle & Duckworth, 1977; Evan & Baker, 1977).

Current experts in the field caution science educators about attitude research (Shrigley, & Koballa, 1992). Shrigley, & Koballa (1992) have stated that "despite the volume of attitude research, only a few faltering conclusions can be deduced regarding the influence of instructional treatments on attitude..." (p 17). Many experts agree that the major problems with past attitudinal research are: a) an inconsistent definition of attitude (Germann, 1988); b) the lack of a theoretical framework; and c) faulty attitude assessment instruments (Koballa, 1992; Koballa & Crawley, 1985; Munby, 1983; Shrigley, 1990; Shrigley & Koballa, 1992). Therefore, in designing a study that would examine attitude, it was important to obtain a definition of attitude, a theoretical framework, and a valid attitude instrument. The following section presents a definition of attitude, a valid attitude instrument, and a theoretical framework on which to base this study.

Definition of Attitude

Germann (1988) suggests that lack of theoretical framework and faulty attitude instruments are due to a" vague, inconsistent, and ambiguous" definition of the construct (p. 689). He argued that there is a difference between scientific attitude, attitude toward science instruction, and attitude towards science itself. Attitude toward science involves scientists, careers in science, and science as a subject. Scientific attitude is more involved in the " approach a person assumes for solving problems, for assessing ideas and information and for making decisions" (p. 690). Koballa and Crawley (1985) defined attitude toward science as the " general or enduring positive feeling toward science" (p 223).

In a more general view, Gagné (1985) defined attitude as choosing some personal action based on one's cognition and feelings. One must have some understanding of related concepts and/or information for an attitude to be acquired. Some attitudes can be acquired due to constant reinforcement. Repeated failure can contribute to the acquisition of a negative attitude.

Since a major goal of the 3 Rs course is to foster positive attitudes in science so that students enrolled in the course might choose science as a career, the students must have an interest in studying the subject, science. Therefore, it is important to examine attitude toward science. This attitude can be defined as the enduring positive and/or negative feelings students have toward science and science as a subject.

Attitude Assessment Instrument

One of the major problems identified with past attitude research was the use of poor attitude instruments. Most instruments used in previous attitude studies provided poor psychometric data (Blosser, 1984; Gardiner, 1975; Mundy, 1983). Many instruments failed to provide psychometric data to provide evidence for reliability and or validity (Germann, 1988). The instrument chosen for this study, *Attitude Toward Science in School Assessment* (Germann, 1988) was selected because of its internal reliability and because the items on the instrument measure attitude toward science.

Attitude toward science involves scientists, careers in science, and science as a subject.

In order to determine construct validity, Cronbach's alpha was calculated and a factor analysis of the items was completed. In previous studies, Cronbach's alpha for all items ranged from .93 to .97. (Germann, 1988). Factor analysis percent of variance for all items ranged from 59.2 to 69.8. Cronbach's alpha for all fourteen items for this study was determined to be .96. For conducting the factor analysis, the items on the instrument were placed into one of two categories: a) interest in science, which has been identified as a major factor in choosing a career (Entwistle & Duckworth, 1977, Evan & Baker, 1977; Hill et. al., 1990), and b) study of science as a subject. Questions in the interest in science category related to how well students like science (i.e., Science is fun.). Items placed in the study of science category related to how students like studying science (i.e., If I knew I would never go to science class again I would be sad.). Variance accounted for by each question for each category or factor loading is reported in Table 1.

Theoretical Framework

On the basis of the review of the literature, constructivist methods of teaching took place in the 3 Rs course. Students worked to construct their own knowledge in both the physical and social environments. In the social environment, they worked in cooperative groups in pairs or in three's. They interacted and discussed phenomena they observed. They were often asked to predict answers to questions and situations. Dialogue was encouraged between students and instructors. This allowed both students and instructors to identify misconceptions students held with regard to physical phenomena.

Students interacted in the physical environment by using the tools of physicists to solve problems in which there was not one correct answer. Working in the physical environment also allowed students to identify misconceptions they held in regard to physical phenomena. In correcting their misconceptions, students became more knowledgeable about physics.

Table 1
Percent of Variance Explained

Factor Loading: Study of Science

Question	% of Variance
I do not like science and it bothers me to study it.	87.394
Duirng science class I am usually interested.	88.727
I would like to learn more about science.	78.970
If I knew I would never go to science class again I would be sad.	77.061
Science is a topic I enjoy studying.	90.964

Factor Loading: Interest in Science

Question	% of Variance
Science is fun.	92.568
Science is interesting to me and I enjoy it.	89.263
Science makes me feel uncomfortable...	82.948
Science is facinating and fun.	84.291
The feeling I have towards science is a good feeling	93.493
I have a definite positive reaction to science	85.894
I feel at ease with science...	89.832
I feel a definite positive reaction to science	90.123

The intent of the course was for students to realize that as women and minorities, they could be successful in science courses and science courses could be enjoyable. Theoretically, this challenged their beliefs they held about science courses. By challenging students beliefs, their beliefs could be changed, thus their behavior, choosing science as a career or choosing to enroll in other science courses, could be changed. Measuring changes in attitude would allow the researcher to identify changes in these beliefs.

Attitude Summary

Science educators are interested in studying attitude toward science because it is an antecedent to behavior. The 3 Rs project's goal is to affect career choice as a behavior. Interest in science courses has been identified as part of the attitude that precedes career choice. In order to change the behavior, career choice, science educators must change attitude. Appleton's model can be used to lead students to changes in attitude via changes in beliefs because beliefs are cognitive.

In order to change beliefs, students must be presented with situations that are contrary to those beliefs. A goal of the 3 Rs course is to change students' beliefs by showing women and minorities that they can be successful in physics and enjoy studying physics as a subject. Practices that are constructivist in nature can facilitate this change. These changes in attitude will be measured using a valid attitude instrument.

CHAPTER III

METHODOLOGY AND PROCEDURES

Introduction

The purpose of this study was to investigate the effects of a constructivist learning environment on cognition of mechanics and students' attitudes toward science. The purpose of this chapter is to describe the methods and procedures used in this study. Case study methodology was utilized to collect and analyze data. Such qualitative research has often been identified as unscientific in its approach (Lincoln & Guba, 1985), although many qualitative researchers such as Stake (1985) have demonstrated the rigor of well designed qualitative research using case study methodology.

Gubba (1991) suggested methods that make qualitative research as rigorous as quantitative research. In a scientific study it is important to establish internal and external validity, reliability, and objectivity. Gubba believes that established credibility can be used in place of internal validity. He also suggested that transferability can be used in place of external reliability, that dependability can replace reliability, and that confirmability can replace objectivity. By establishing credibility, transferability, dependability, and confirmability, a well developed case study, if not scientific study, can be established. Gubba refers to these elements of a study as the trustworthiness of a study. The following section provides a description of the how the trustworthiness of this study was achieved.

Trustworthiness of the Study

The trustworthiness of this study was established by the constructs identified by Lincoln and Gubba (1985). According to Lincoln and Gubba (1985), the trustworthiness of a study can be established through credibility, dependability and confirmability, and transferability.

Credibility

Gubba and Lincoln state credibility can be established through prolonged engagement, persistent observation, peer debriefing, participant checking and triangulation.

In this study, the investigator was involved in the Three R's project for twelve months prior to the study and for four months during the collection of data. The investigator was present at all class meetings that were two hours in length three times per week. A journal of the graduate assistant's observations and impressions was kept during this time. This established prolonged engagement and persistent observation.

Peer debriefing "is a process of exposing oneself to a disinterested peer in a manner paralleling an analytic session" (Lincoln & Gubba, p 308). The purpose of this session is to identify any aspects of the study that are not expressly stated by the inquirer. For this study an anthropologist, familiar with case study methodology, and a physicist, familiar with physics education research, reviewed the case study account.

In order to establish participant checking the interviewer read the presentation of interview results to confirm accuracy and interpretations of the interviewees' comments. She confirmed that interviewees' statements were accurately presented and not taken out of context.

According to Lincoln and Gubba, triangulation of the data can occur when using different data collecting modes. Since multiple data sources were used, triangulation of the data could occur within student groups, among different sources, and within sections. The participant observation journal also facilitated triangulation of the data.

<u>Dependability and Confirmability</u>

Lincoln and Guba have stated that there cannot be "validity without reliability and thus no credibility without dependability" (p 316). Dependability was established by an inquiry audit. The instructor for the 3 Rs course examined the process by which the accounts of the inquiry were kept and he examined the records for accuracy. He also examined the data, an account of the findings, and the interpretations of those findings. He determined that the dependability of the study was established.

Confirmability was established through a confirmability audit, triangulation, and a participant observation journal. The confirmability audit was made of the raw data, a flow chart identifying how the data was analyzed, and data reduction and analysis products. A flow diagram is provided in Figure 2 to describe the exact sequence by which the data was analyzed.

<u>Transferability</u>

Gubba and Lincoln have stated that transferability can be established through 'thick description'. The combination of multiple data sources and the number of participants provided an adequate data base that allowed transferability judgments to be made. The triangulation of evaluation instruments, tests, examination, course work, participant observation notes, and interviews provided a thick description of the case that existed in the Three R's course in the fall of 1994. Transferability can thus be established by the techniques used for facilitating thick description.

Case Study Methodology

According to Yin (1984) there are five components of the case study research design. These are: a) a study's questions; b) the propositions of the study; c) its unit(s) of analysis; d) the logic linking the data to the propositions; and e) the criteria for interpreting the findings. These components are described in the following section.

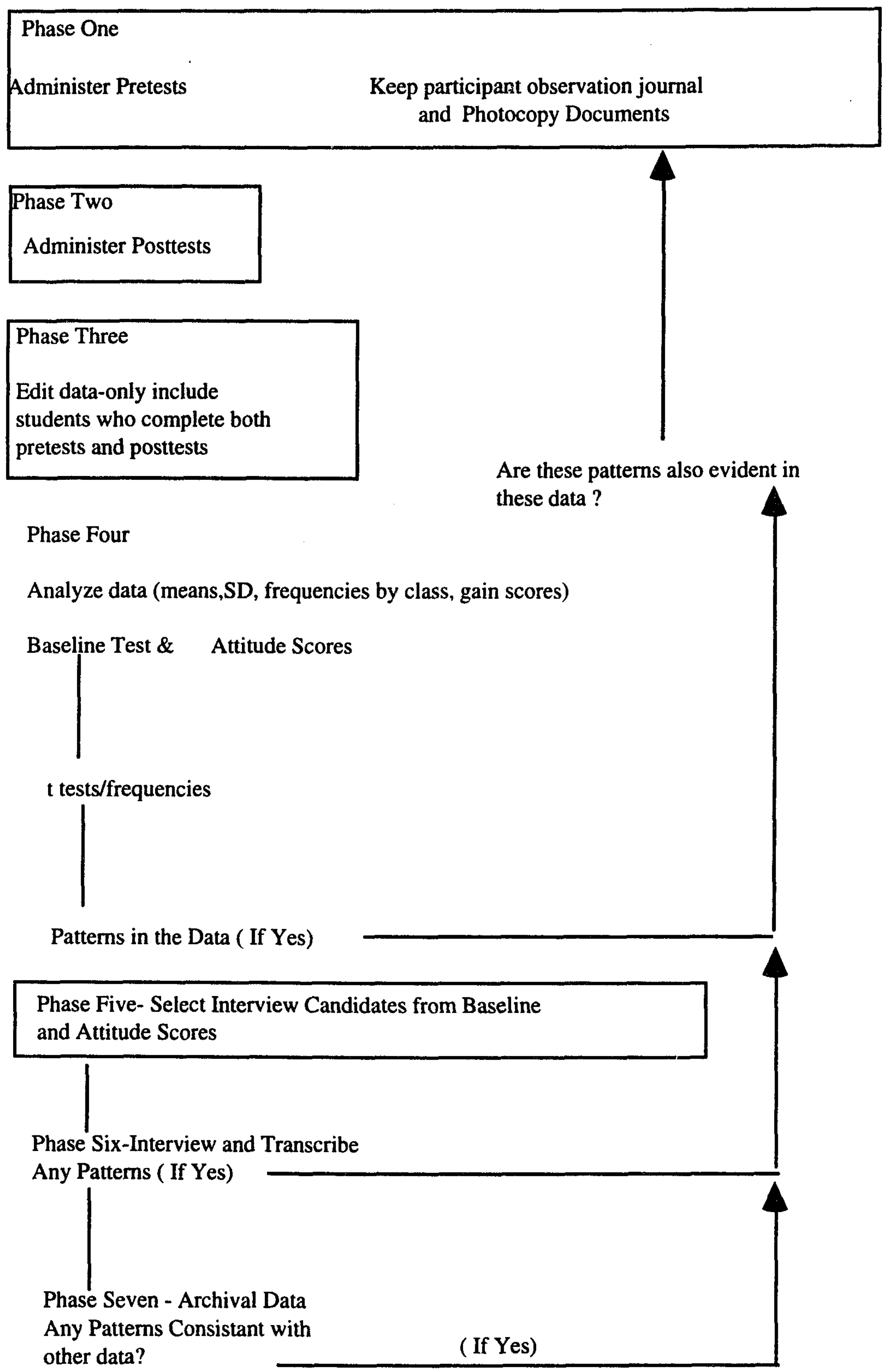
Study questions

There are two hypotheses that were generated based on the review of the literature:

1) Students enrolled in the 3 Rs course will have a greater change in understanding physics concepts related to mechanics than students enrolled in a traditional physics course.
2) Students enrolled in the 3 Rs course will exhibit more positive changes in attitudes towards science than students enrolled in a traditional physics course.

Study propositions

A proposition should "direct attention to something that should be examined within the scope of the study" (Yin, 1984, p 31). The theoretical model developed for this study was based on the literature presented in the


Phase One
Administer Pretests
Keep participant observation journal and Photocopy Documents
Phase Two
Administer Posttests
Phase Three
Edit data-only include students who complete both pretests and posttests
Are these patterns also evident in these data ?
Phase Four
Analyze data (means,SD, frequencies by class, gain scores)
Baseline Test &
Attitude Scores
t tests/frequencies
Patterns in the Data (If Yes)
Phase Five- Select Interview Candidates from Baseline and Attitude Scores
Phase Six-Interview and Transcribe
Any Patterns (If Yes)
Phase Seven - Archival Data
Any Patterns Consistant with other data?
(If Yes)

proceeding chapter. The literature reviewed suggests that both student cognition and beliefs, and subsequently attitudes, can be guided through conceptual change by using certain teaching strategies and providing the proper learning environment.

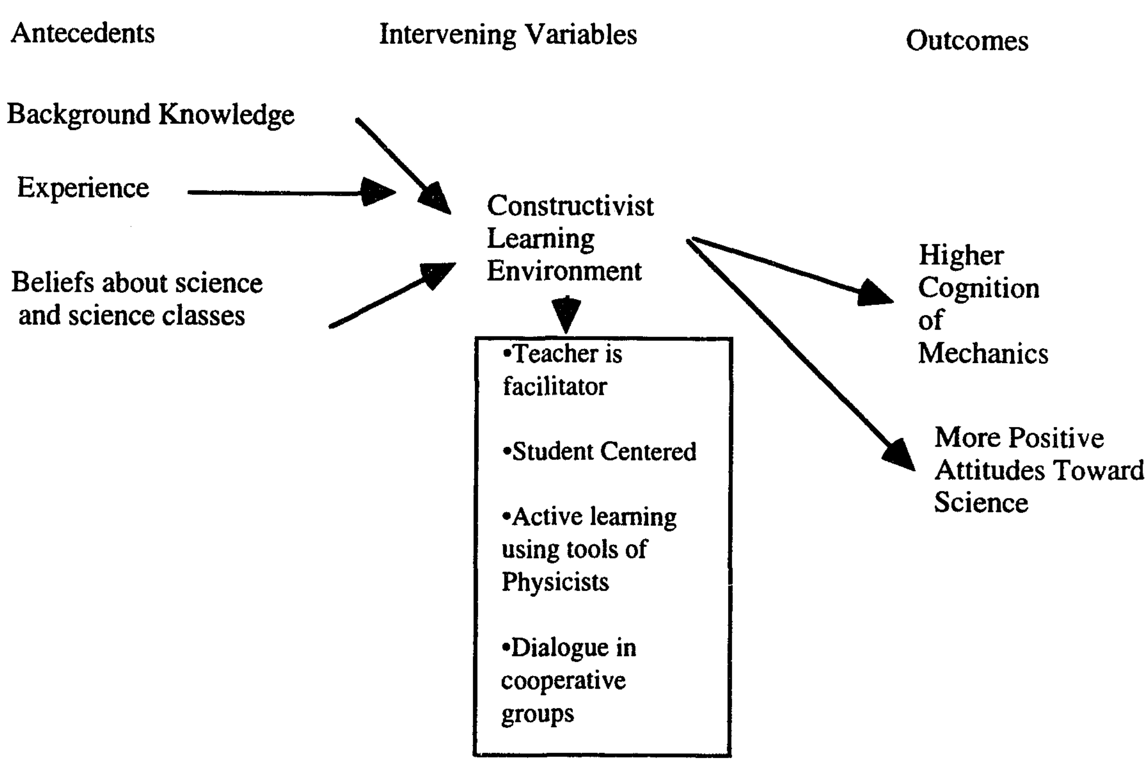
Gagné (1985) believes if a student is successful, he or she understands the material, then the student is more likely to have a positive attitude toward science. It is therefore important to establish an environment in which student understanding is maximized. Research indicates that students have a more positive attitude if material is related to everyday life (Glasson & Lalik, 1993). The review of the literature also found that students enter the classroom with pre-existing attitudes and conceptions, both of which can affect learning and attitude (Arons, 1987; Arons, 1990; Brown, 1992; Dykstra et al., 1992; McDermott, 1984). It was found when the teacher assumes the role of conceptual bridge builder, misconceptions can be identified and corrected (Andrews & Meisner, 1993).

The theoretical model adopted for this study assumes that the learner enters the learning environment with prior knowledge. Prior knowledge includes both misconceptions (Arons, 1987; Arons, 1990; Brown, 1992; Dykstra et. al., 1992; McDermott, 1984) and preexisting attitudes, based on students' beliefs, toward science (Koballa, 1987: Shrigley, 1990). It is important to include prior knowledge in the model because constructivists believe that learning begins with prior knowledge (Appleton, 1993). The model is interactive because the learner interacts with the learning environment (Yager, 1991). He or she does this in the physical environment by interacting with the tools of physicists to solve problems encountered in everyday life

(Roth, 1993) and in the social environment by working in cooperative pairs (Wheatley, 1991). The environment includes use of constructivist strategies such as employing problem solving strategies, collecting and organizing data, experimenting with materials, using student responses to drive the lesson, applying knowledge and skills, and use of microcomputer-based laboratories (MBL). Use of these strategies allows the learner to construct knowledge and provides opportunity for the instructor to identify discrepancies in students' existing frameworks (Yager, 1991). See Figure 3 for a schematic drawing of the model.

Figure 3

Theoretical Model



Units of Analysis

The units of analysis for this study were two sections of students enrolled in Physics 101 in the fall semester of 1994. The units of analysis were the two sections. Only those students who completed both pretests and both posttests were included in the data base. Participation in the study was strictly voluntary. Twenty-one students out of a total class size of twenty-four students from the 3 Rs section and thirty-one students of ninety from the traditional lecture course elected to participate in the study. They completed all pretests and posttests and were therefore included in the data base. The two courses differed in various ways. A description of each section is provided in the following section.

The 3 Rs

The 3 Rs class met three times per week and was two hours in length. Most of the class was spent completing laboratory activities (see Appendix A for syllabus). The lab activities were not verification labs. Frequently there was no 'right answer' (see Appendix A for a sample laboratory activity). There was very little lecture. Instructors and the graduate assistant circulated to assist students if needed and question students to facilitate understanding.

The students were given an agenda for each class period so that they knew what they should accomplish by the next class meeting. See Appendix A for a typical class agenda. Often students had to spend additional time in the lab after regular class hours in order to complete assignments.

Each Friday students took a 'concept quiz' so that the instructor and the students could identify any weaknesses in student knowledge or misconceptions that existed in the students' conceptual framework (see

Appendix A for an example). Students were given four two hour examinations through out the semester. Three of these tests consisted of two parts. Part one was a traditional pen and paper multiple-choice test in which students were given 20 problems to solve. For part two, students were required to design and execute an experiment to solve an assigned problem. For example, for one test students were to determine the amount of kinetic energy lost when a softball collided with a wall. Students completed part two with their cooperative group. Two of the four multiple choice tests were taken in the cooperative group. The other two were taken individually as was the final examination.

A constructivist learning environment existed in the 3 Rs course. Instructors consistently used students' background knowledge to drive lessons. Interaction continually took place between the learners, instructors, and the environment. The curriculum materials used in the course facilitate this interaction. An example of how this occurred is provided below.

Students in the 3 Rs Physics Course used Workshop Physics activities developed at Dickinson College (Laws, 1990) in Pennsylvania and Tools for Scientific Thinking activities developed at TUFTS University in Boston, Massachusetts. Both sets of materials demanded that students use problem solving skills and both were open-ended. Students worked in cooperative groups to collect and organize data using Vernier software and probeware connected to the Macintosh computer. A typical lesson is a TUFTS investigation in which students were to observe acceleration and velocity graphs produced from the motion of a dynamics cart down a nearly frictionless incline plane. After setting up the apparatus, students were asked to generate a hypothesis as to what they thought would happen. The students then collected one set of data. The students were then asked to change the angle of the incline. After changing the angle several times, students were asked to draw conclusions about how the angle of the incline affected acceleration and velocity. The students then had to explain how their observations differed from their hypothesis. This provided opportunity for dissatisfaction.

During the lesson, the instructors circulated the classroom to assist students and ask questions to identify discrepancies in students' conceptual frameworks. If necessary, the instructor could then assume the role of conceptual bridge builder to guide the student through conceptual change.

The Lecture Section.

The traditional lecture section met three times per week for fifty minutes in a large lecture hall. The instructor stood at the front of the room to conduct class. He often demonstrated physical phenomena for the class. The instructor worked problems related to material that was being covered and conducted demonstrations to illustrate phenomena being discussed in class (see Appendix A for syllabus). He felt it important to make the class fun and interesting. He was readily available outside of class to help his students.

The students were required to attend a laboratory once per week that was scheduled for three hours. The laboratory activities were verification labs in which there was often one right answer (see Appendix A for an example). Students frequently finished the lab before the scheduled time was completed. A summary of the difference between the two groups can be found in Table 2.

Table 2

Comparison of the Sections

3 Rs Class	Lecture Class
Student Centered	Instructor Centered
Interactive Learning	Passive Learning
Authentic Labs	Verification Labs
Cooperative Groups	Individual Learning

Linking data to the propositions

The data collected was both quantitative and qualitative in nature. Quantitative data was collected by administering evaluation instruments to measure student attitudes toward science and student cognition of mechanics. Students were administered both of these instruments as both a pretest and posttest. These data were analyzed using statistical methods to compare pretests and posttests mean scores of both groups. Yin (1985) has suggested there should be multiple sources of qualitative data that should be placed into a data base. The data base for this study was drawn from documentation, archival records, interviews, and participant observation. The specifics of these data, both quantitative and qualitative are presented in the following section.

Quantitative Data

Attitude Toward Science in School Assessment

Special care was taken when selecting the instrument to measure changes in student attitudes. A major problem that has been identified with past research was the use of poor attitude instruments (Blosser, 1984; Gardiner, 1975; Mundy, 1983a, 1983b; Schibeci, 1983). Many instruments did not provide psychometric data to provide evidence for reliability and/or validity (Germann, 1988). The instrument chosen for this study, *Attitude Toward Science in School Assessment* (Germann, 1988) was selected because of its internal reliability and the items included on the test measured the construct, attitude toward science.

The *Attitude Toward Science in School Assessment* instrument is a Likert-type instrument with fourteen items (see Appendix B for a copy of the instrument). Germann (1988) reported Cronbach's alpha for all items on the test from previous studies ranged from .93 to .97. He also reported factor analysis percentage of variance for each individual question ranged from 59.2 to 69.8. See Table X for details. Cronbach's alpha for all fourteen items for this particular study was determined to be .96. Variance accounted for by each questions for each category is reported in Table 1 in Chapter II.

Cognition of Mechanics

The *Mechanics Baseline Test* was chosen to measure student cognition because of its content and the psychometric data provided (see Appendix B for a copy of the instrument). The test was designed to assess student understanding of basic mechanics concepts. First semester physics course content at The University of North Carolina at Greensboro is mechanics. The Baseline Test was developed to assess students' understanding of the first semester of introductory physics and it emphasizes concepts that can not be understood without formal understanding of mechanics (Hestenes & Wells, 1992).

The Baseline Test upon first examination looks like a quantitative problem-solving test. However, it was designed to measure qualitative understanding (Hestenes & Wells, 1992). The multiple choice distracters are not common-sense alternatives and they include typical student mistakes. These mistakes are made due to deficiencies in understanding rather than carelessness. There are no problems on the test where numbers can be 'plugged in'.

There are twenty-six multiple choice items on the test. Seven of these items require greater than average amount of calculation than other items on the test. Seven items require the use of force diagrams to answer the question. Twelve items are related to kinematics. Two items can be placed in all three categories (Hestenes & Wells, 1992).

The test has been administered to both high school and college students. The test was administered to college students enrolled in introductory physics courses at Arizona State University (AVH) and Harvard University (HU). These student scores, the percentage obtaining the right answer, means and standard deviations for students in Physics 105 at AVH and regular and honors sections of physics at HU as well as those from Wells High School and students in Arizona high schools can be found in Table 3. There was no information available on the validity nor the reliability of this test.

Qualitative Data

In any qualitative study, data from multiple data sources should be collected (Yin, 1985). The data base for this study was drawn from documentation, archival records, interviews, and participant observation. A

Table 3

Mechanics Baseline Data

Question Number	AZ Regular %correct	AZ Honors	AP %correct	MW Regular	MW Honors %correct	AVH	HU Regular %correct	HU Honors
1	54	69	69	61	73	79	78	75
2	40	51	56	39	70	78	78	82
3	29	44	59	50	70	60	93	90
4	85	80	84	94	90	86	67	69
5	1	1	3	11	40	72	18	12
6	45	44	56	61	73	53	87	96
7	8	8	25	22	40	46	36	38
8	23	30	31	72	83	67	81	92
9	21	23	25	17	47	40	68	86
10	35	43	28	61	97	50	89	932
11	25	26	34	17	40	47	85	85
12	12	17	9	6	17	29	24	30
13	31	37	47	56	83	69	79	82
14	51	56	75	83	93	76	87	100
15	48	47	41	56	83	79	83	90
16	16	17	9	22	47	38	60	73
17	26	33	31	22	63	60	81	81
18	15	19	25	28	20	40	32	51
19	16	17	34	39	47	29	78	84
20	25	24	9	28	70	38	46	49
21	62	71	53	61	83	93	89	97
22	56	49	53	61	40	67	32	48
23	28	41	44	39	53	74	84	85
24	29	50	44	17	70	35	59	74
25	25	37	38	33	67	26	61	70
26	13	20	28	28	57	31	53	71
Test Ave	32	37	39	42	62	61	66	73
(Standard Deviation)	(11)	(15)	(15)	(16)	(17)	(18)	(14)	(11)
Calculation	31	33	30	31	45	51	54	64
Diagram	14	17	24	27	43	45	46	53
Kinematics	30	39	41	39	58	57	62	68
Number of Students	600	116	32	18	30	58	183	73

detailed description of these data sources can be found in the following section.

Documentation

Documentation for this study consisted of copies of laboratory classwork, individual and group tests, including part one and part two reports, and individual quizzes. Examination of these documents allowed the researcher to identify misconceptions held by students and/or identify factors that might interfere with student cognition. Therefore, copies of laboratory classwork were photocopied from the eleven lab groups from Unit Nine, Torque; Unit Eleven, Pressure; Unit Twelve, Heat and Temperature; and Unit Fifteen, Thermodynamics. Photocopies of individual and group tests were made from part one of all tests and the final exam. Part two reports from exam one, the effects of adding springs on the spring constant, and the final exam, parameters that affected terminal velocity of an object, were also photocopied. Concept quizzes on pressure and temperature were also included in the data base.

Archival Records

Archival records were drawn from past data bases assembled from previous semesters of research conducted with 3 Rs class members. These records include Mechanics Baseline test scores, course evaluations, interviews, and surveys completed by Fall 1994 students prior to the study which provided background information about the students. These records would allow the researcher to determine if patterns that occurred in the fall semester were also prevalent in other 3 Rs sections from previous semesters.

Interviews

Interviews were conducted to provide another data source from which to identify changes in student cognition and attitude toward science. The researcher wanted to draw a sample from the two groups that was typical of both sections. In order to select students for the interview process, students' scores on the Baseline test and the *Attitude Toward Science in School Assessment* instrument were examined. Two students from each section with above average attitude and above average Baseline scores, two students with average attitude and average baseline scores and two students from each section with below average baseline and below average attitude scores were placed on a master list. Six alternates were then chosen. Students were asked if they would be willing to participate in an interview conducted by a skilled interviewer who was not involved in teaching or grading either section. Students were to be interviewed about their experience in physics for the fall semester. Students who indicated a willingness to be interviewed were then matched to a master list. The first four pairs of students on the master list were interviewed as well as the sixth and seventh pairs.

The list of students' codes was then provided to the interviewer. She contacted the students and arranged interview appointments. Students who participated in the interviews were compensated for their time. Interviews were conducted formally at the beginning of the spring semester. Interview questions can be found in Appendix C. The interviews lasted no less than twenty minutes and no more than one hour. All interviews were transcribed and the researcher had no access to the original audio tapes or to the identities of the students participating in the interview.

Participant Observation

Participant observation was documented by a teacher assistant journal. The journal was kept on the computer. Entries were made at least once each week. Observations were recorded as soon as possible after the class session in which the observation occurred. Six two-hour sessions of the 3 Rs class were videotaped. Three of these class sessions were on heat and temperature, two were on heat transfer, and one was on thermodynamics. Using video taping allowed the participant observer to observe these class sessions at leisure.

The participant observer also was a passive observer in three laboratory classes of the lecture section. Observation notes were made of each session.

Collecting the Data

The data for this case study was collected in the fall of 1994. Documentation occurred during this time. Both *Mechanics Base-Line Test* and *Attitude Toward Science in School Assessment* were administered in September to students enrolled in both sections of Physics 101. These evaluation instruments were also administered as posttests the last week of the semester. Copies of laboratory reports and tests and quizzes were made throughout the semester. Video recordings of six two hour sessions of the Three R's were made from lessons on heat and temperature, heat transfer, and thermodynamics. Interviews were conducted and transcribed at the beginning of the spring semester, 1995.

Analyzing the Data

Quantitative Data

The pretest and posttest for both the Mechanics *Base-Line Test* and Attitude *Toward Science in School Assessment* were analyzed using statistical analysis. The difference in the pretest and posttest scores for every student in each group was calculated using SAS. The mean for each group also was calculated. An independent $\underline{t}$ test was used to test the following null hypotheses for both the Mechanics *Base-Line Test* and Attitude *Toward Science in School Assessment*: a) the mean pretest score for the 3 Rs was equal to the mean pretest score for the lecture section; b) the mean posttest score for the 3 Rs was equal to the mean posttest score for the lecture section; and c) the mean difference in pretest and posttest scores were equal. A significance level of .10 was chosen because of the small sample size (n=2). A critical value of 3.078 (1 degree of freedom) was used in determining if differences were significant.

The *Mechanics Base-Line Test* also was examined using a Chi Square analysis to test the difference in proportions of correct answers on grouped and on individual questions (Glass & Hopkins, 1984). Questions on the test were divided into three groups: a) questions related to force diagrams; b) questions related to kinematics; and c) those that required calculations. A significance value of .05 was chosen. A critical value of 3.84 was used in determining if differences were significant.

Qualitative Data

The qualitative data was analyzed through relying on theoretical propositions using pattern matching logic (Yin, 1985). Emerging patterns were matched to predicted ones. The data was prepared by transcribing the interviews and portions of videotapes to facilitate identification of patterns in the data and matching these patterns to patterns identified in other data sources. A coding system was devised that allowed commonalties to be identified. Patterns contrary to the theory were purposely sought as well as unhypothesized patterns that emerged. The researcher deliberately sought disconfirmation of findings (Stake, 1988).

More specifically, classwork, quizzes, tests, and the examination, were examined for misconceptions and /or problem areas. These were coded and grouped by commonalties. The videotapes of the two hour class sessions on heat and temperature (two sessions), heat transfer (two sessions), and thermodynamics (two sessions) were examined for disequilibrium and statements that included misconceptions. The transcript of the video tape was coded according to the path the student took in Appleton's model. Student redirection was then coded according to the apparent source of the redirection (i.e., instructor questioning, dialogue with lab partners, and or interaction with the physical environment).

Formal interviews were audio taped and transcribed. The transcribed documents were coded according to emerging themes present in the interviews.

Triangulation of the data first occurred by matching emerging patterns that occurred between laboratory groups, second by matching patterns across data sources, and third by matching patterns that occurred among sections.

CHAPTER IV

DATA PRESENTATION AND ANALYSIS

Introduction

The purpose of this chapter is to present an analysis of the data collected as it documents student cognition and attitude during the course of this study. The results from the Mechanics Baseline Test are presented first. The results of pattern matching analysis of the course work, quizzes and tests follow the analysis of the Baseline Test. The results of the *Attitude Toward Science in School Assessment* instrument are then presented followed by results from the student interviews. This is followed by a discussion of how well the theoretical model fits the data.

Student Cognition

The Mechanics Baseline Test

Students were administered the Mechanics Baseline Test six weeks into the semester as a pretest. The mean for the Three R's section was 7.048 (SD=2.46) questions answered correctly. The mean for the lecture section was 7.94 (SD=3.79) questions answered correctly. In order to determine the appropriate t test to be used, an equality of variance F statistic was calculated. The $F_{(30,20)}$ statistic was determined to be 2.38 . Since this statistic was significant at the .10 level it was determined that the variances were unequal and an unequal variance t test procedure was then conducted. The t statistic was calculated to be -1.024_{1df}. This test statistic was not significant at the .10 level. It was therefore determined that there were no differences in the pretest scores for the two groups.

The posttest was administered the last week of the semester. The mean correct questions for the 3 Rs group was 7.59 (SD=2.28)and the mean correct questions for the lecture section was 8.16 (SD=3.07). In order to determine which t test should be used, an equality of variance F statistic was calculated. The $F_{(30,20)}$ statistic was determined to be 1.81. Since this statistic was not significant at the .10 level it was determined that the variances were equal and an equal variance t test procedure was then conducted. A test statistic of $-.739_{1df}$ was calculated. This test statistic was not significant at the .10 level and it was therefore determined that there was no difference in the posttest scores of the two groups.

In order to determine if there was a significant difference in the change in knowledge scores between the two groups a gain score was calculated. This score was calculated for each individual student by subtracting their pretest mean from their posttest mean. The mean gain score for the Three R's group was .474 (SD=3.10). The mean gain score for the lecture section was .267 (SD=3.24). An equality of variance F statistic was computed in order that the proper t test be conducted. The $F_{(30,20)}$ statistic was determined to be 1.16. Since this statistic was not significant at the .10 level the variances were considered to be equal. An equal variance t test was then conducted and the test statistic was determined to be $.224_{1df}$. This test statistic was not significant and it was therefore determined that there was no difference in the gain scores for the two groups. See Table 4 for a summary of knowledge scores.

Table 4

Scores for Knowledge Test

Mean	Pretest	Posttest	Gain
Three R's	7.0476	7.5909	.47368
Lecture	7.9355	8.1613	..26667
F statistic (equal variance)	2.38	1.81	1.16
T-statistic (1df)	-1.024	-.7385	.8237

The posttest answers were then divided into three groups based on the type of question: a) those that required a force diagram to obtain the correct answer; b) those that required calculation; and c) those that dealt with kinematics. The mean proportion of questions answered correctly for questions that required a force diagram for the Three R's group was .1557. The mean for the lecture section was .1567. A Chi Square difference in paired proportions was calculated to be $.001_{1df.}$ This was not significant at .05 level. The mean proportion of questions for that required calculation for the Three R's group was .292. The mean for the lecture section was .332. A Chi Square difference in paired proportion statistic was calculated to be $.256_{1df.}$ This was also not significant at the .05 level. Lastly, the mean proportion of questions that dealt with kinematics was calculated for both groups. The mean for the Three R's was .274. The mean for the lecture section was .2956. A Chi Square difference in paired proportion statistic was calculated to be $.082_{1df}$. Again, this was not significant at the .05 level. It was therefore concluded that there were no differences in the proportions of students answering questions correctly for questions that required a force diagram, required calculation, and dealt with kinematics between the two groups. See Table 5 for a summary of grouped questions on the *Mechanics Baseline Test.*

Table 5

Grouped Questions on *Mechanics Baseline Test*

	Mean Proportion Correct Answers		
	3 Rs	Lecture	Chi Square
Force Diagram	.1557	.1567	.001
Calculation	.2920	.3320	.256
Kinematics	.2740	.2956	.082

The posttest answers for each individual question were then examined. The percent of correct answers for each question for the two groups was determined. An item analysis is presented in Table 6. A Chi Square difference in proportions for paired items was calculated for each item. The Chi Square statistic for items 2, 3, 7, 10, 16, 20, and 26, indicated that the proportions of students answering the question correctly was significantly different for the two groups with the lecture group performing best. These items could be placed in one of two categories; those that involved understanding a diagram and those that involved reading a graph. These patterns were also prevalent in the mistakes 3 Rs students made on tests, quizzes, and class assignments.

Problems with diagrams.

Students consistently had problems drawing and/or interpreting diagrams on tests, quizzes, and class assignments. An example of this problem is in Unit Nine; the unit on torque. Students were asked to attach a meter stick with holes drilled in it to a fixed point. The students were to then place two scales at equal distances from the fixed point and to apply equal forces in the same direction at each of these points. They were asked to

Table 6
Item Analysis for Mechanical Baseline Posttest

Question #	3 Rs % correct	Lecture % correct	Chi Square
1	59.1	41.9	2.93
2	18.2	35.5	5.57*
3	22.7	38.7	4.18*
4	81.8	67.7	1.33
5	4.5	3.5	.125
6	40.9	41.9.	012
7	4.5	12.9	4.06*
8	29.3	35.5	1.10
9	31.8	22.6	1.56
10	9.1	67.7	44.7*
11	40.9	25.8	3.42
12	9.1	9.7	.019
13	22.7	16.1	1.12
14	59.1	51.6	.508
15	54.5	48.4	.362
16	22.7	41.9	5.71*
17	18.2	22.6	.475
18	27.3	19.4	1.70
19	36.4	29.0	.837
20	13.6	35.5	9.78*
21	63.6	61.3	.042
22	59.1	58.1	.009
23	18.2	22.6	.475
24	9.12	9.0	.001
25	18.2	29.0	2.47
26	4.5	19.4	9.29*
kinematics (Q's 1,2,3,4,5,8,9,12, 18,23,24,25)	27.4	29.56	.082
calculation (9,11,12,18,20,21,22)	29.2	33.2	.256
diagram (5,7,12,13,18,19,26)	15.57	15.67	.001

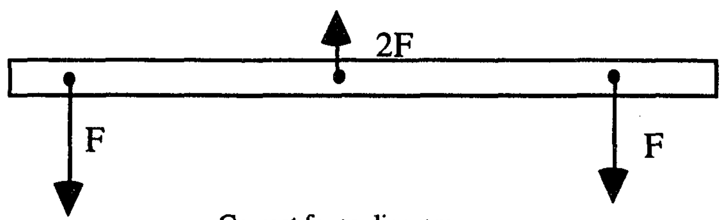
*Significant at the .05 level

observe what happened (no torque was produced). Students were to then draw a force diagram representing the situation. Only 25% of the student groups were able to properly draw the force diagrams. The appropriate force diagram and student examples can be found in Figure 3.

Another example is from Unit Eleven: Pressure. Students were to answer a series of questions based on a diagram (see Figure 4) of a wooden block and an aluminum block in water. Students were to calculate the gauge pressure on the top and bottom on each block. Gauge pressure could be found by first multiplying the density of the object by gravity and by the height the object was under water. Gauge pressure excludes atmospheric pressure. Students were unable to interpret the diagram even after the graduate assistant and one of the instructors explained how to calculate gauge pressure.

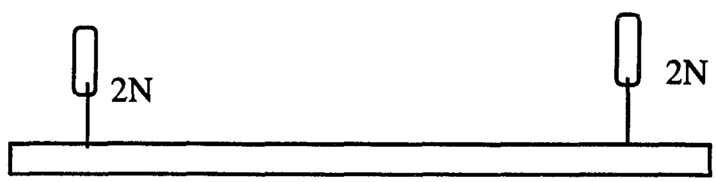
Figure 3

<u>Student Diagrams from Unit 9</u>



Correct force diagram

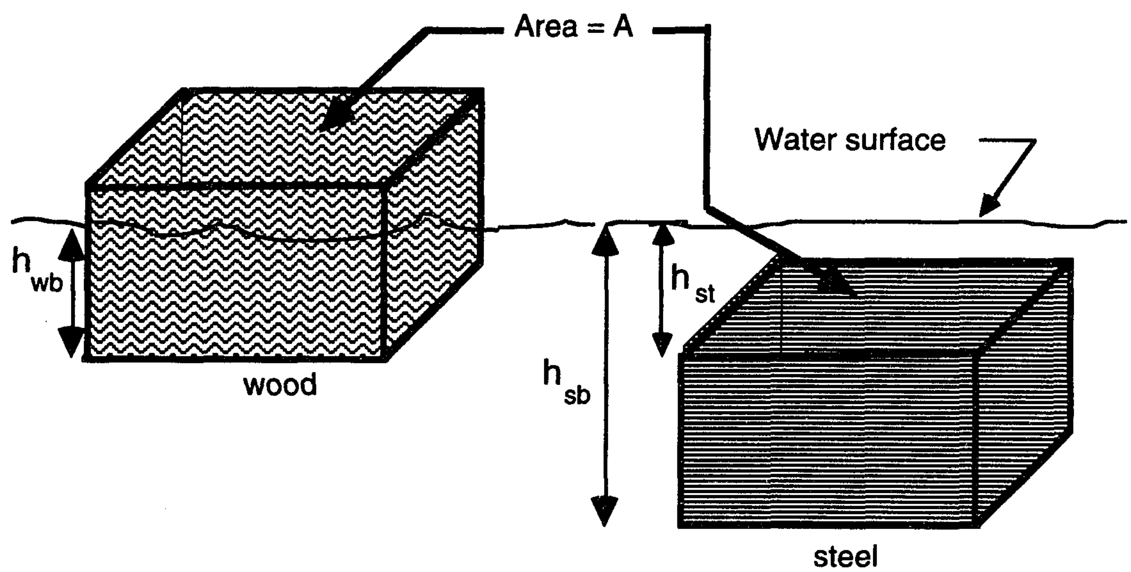
Example of Student Response



*Many students did not attempt to draw a force diagram.
They left the questons blank.

Figure 4

Diagram from Unit 11- Pressure



**Students needed to use the equation P=ρgh to calculate gauge pressure. The students had difficul calculating pressure on top and bottom of the two blocks.

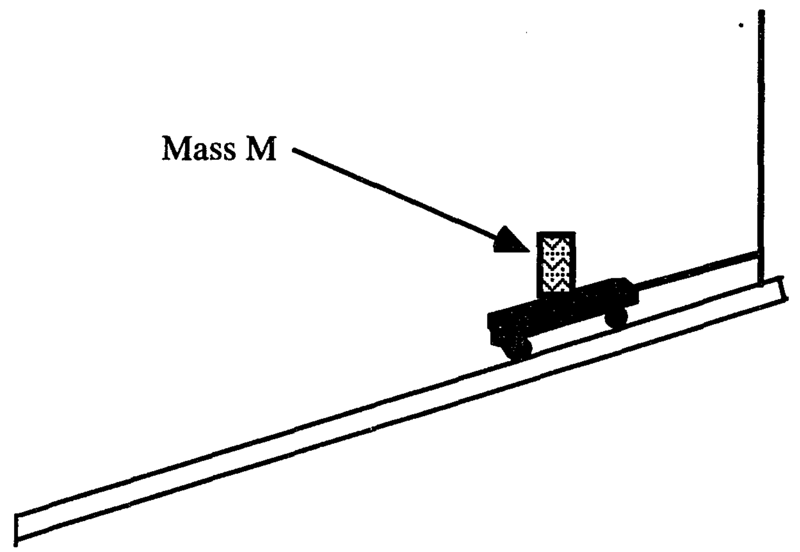
Students inability to interpret diagrams was also a major problem on tests. There were 20 questions on all hourly exams. The final exam had 30 questions. For example, on test one there were twelve questions that at least 50% of the students did not answer correctly. Of these twelve questions ten required obtaining information from a diagram or a student drawn diagram would have been useful in obtaining the answer. The eleventh question missed involved reading a graph. On test two there were sixteen questions on the test that at least 50% of the students did not answer correctly. Of these sixteen, eight required students to obtain information from a diagram. Likewise for test three, of twelve questions missed by at least 50% of the students five required students to interpret diagrams. Test four only had two of nine questions missed by at least 50% of the students required students to obtain information from a diagram. The final exam, however, was more similar to the first two exams. There were 24 questions out of 30 that at least 50% of the students answered incorrectly. Eight of these 24 questions required that students obtain information from a diagram or a diagram was needed to correctly answer the question. Three of the eight diagrams were force diagrams.

The interview data also support the finding that 3 Rs students could not properly read and interpret diagrams. When students were asked to identify all forces in the situation in Figure 5, only one Three R's student was able to correctly identify all forces. All of the 3 Rs students were able to identify the force on the dynamics cart due to gravity. Three of the six Three R's students were able to identify the normal force acting on the cart and only three students were able to identify the tension force in the attachment. Two of the six students included the frictional force.

The lecture section students, however, were very successful in identifying the forces acting on the dynamics cart. All but one of the lecture section students correctly identified these forces.

Figure 5

Correct force Diagram for Interview



Problems with graphs.

Students in the Three R's section not only had problems interpreting diagrams on the Mechanics Baseline Test , they also had problems reading graphs. This was a second pattern that was prevalent in mistakes students continually made on quizzes, classwork, and tests. For example, on Concept Quiz 14, students were asked to determine absolute zero on "New World" in a different universe. To do this students needed to extrapolate a graph (see Figure 6). Seventy-four percent of the students were unable to do this. On the final exam 12.5% of the questions missed by at least 50% of the students involved reading a graph. Misunderstanding of graphs was also prevalent in classwork. In Activity 15-2, 41.6% of the student lab groups could not interpret the graph of pressure and volume (See Figure 7) and therefore could not complete the activity. Earlier in the semester many students had an especially difficult time drawing acceleration graphs from velocity graphs and visa versa. Even the 'A' students had difficulty reading graphs as was evident during a class discussion on heat and temperature:

Instructor	"Do you have any questions about the pretest ?"
Student	"I have a question."
Instructor	"Yes?"
Student,	" On number four I got 200 calories per gram and that is not an answer."
Instructor,	" You got 200 as an answer and 200 is not an answer. You know some of these answers might be wrong" He reads the question. " Why do you say the answer is 200?"
Student	"Because if you look at the graph the difference in temperature on that straight line is 200."
Instructor	" I think you are reading the graph a little incorrectly. Part of the reason is the zero point isn't as clear as it might should be. The zero point crosses the y axis. That first hash mark is 50. The next one is 100, its marked. That next one is 150, not 200. That line you are correctly looking at goes from 50 to 150. That's a difference of 100 calories per gram, not 200. Your thinking process was entirely correct. You just misread the graph."

Figure 6

<u>New World Temperature/ Concept Quiz 14</u>

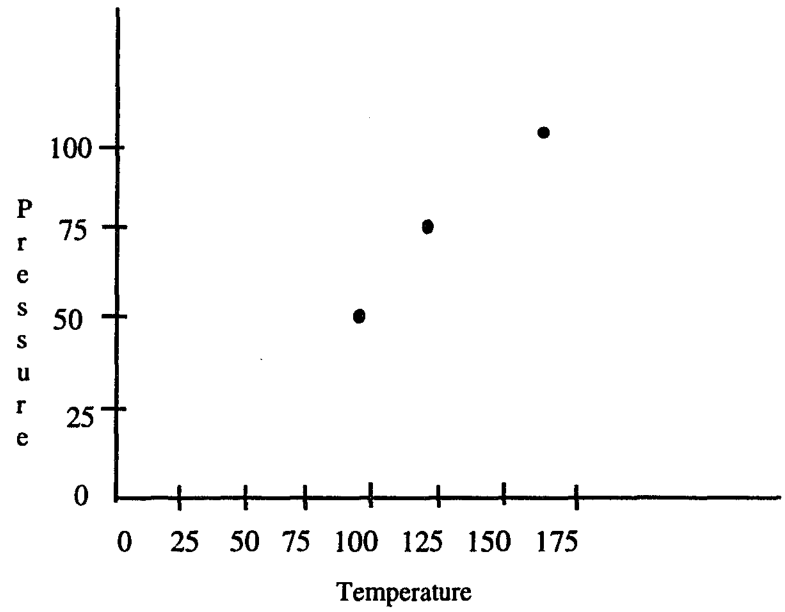
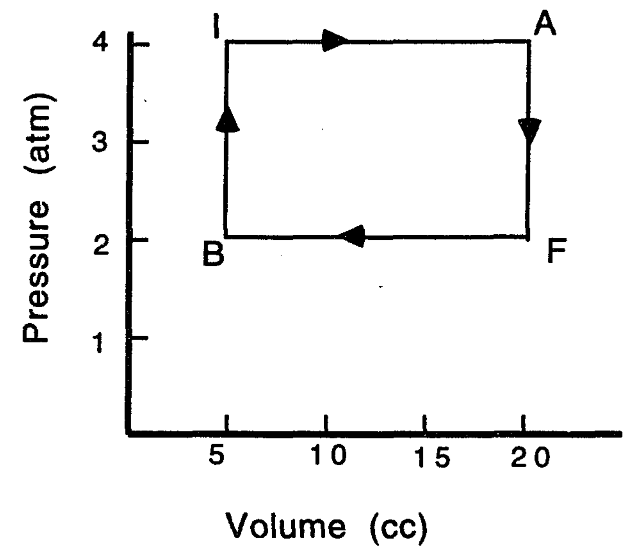


Figure 7

Unit 15: Thermodynamics Graph



Students were asked "Suppose you wanted to operate your syringe so that the air pressure and volume followed the path shown above:

1. Compress the air in the syringe to give pressure of about 4 ATM and a volume of 5 cc. (It does not have to be accurate). The gas is now at point I in the diagram. What would you have to do to move from I to A on the diagram; i.e., expand the gas at the same pressure? Explain your answer. (You cannot change the amount of air in the syringe).

2. If the gas is at point A, what would you have to do to move the air from A to F; (i.e., decrease the pressure while keeping the volume constant)? Explain.

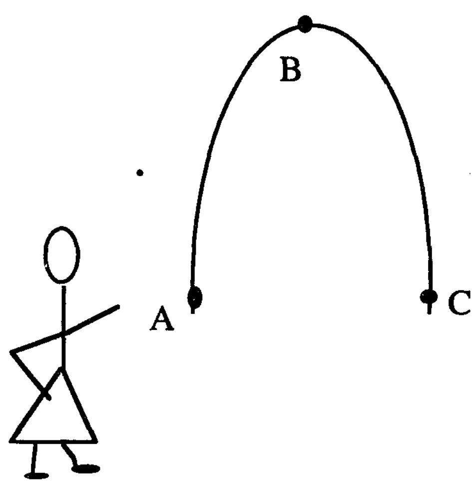
The interview data suggest that Three R's students understood velocity and acceleration graphs. All six students who participated in the interview were able to correctly draw the acceleration graph that would match the velocity graph provided. Two of the six students could not correctly draw the force diagram. Only two students in the lecture section were able to correctly draw both the acceleration and force graphs from the velocity graph. One other student correctly drew the velocity graph.

Other problems prevalent in the data.

Another pattern identified in the data was that students were unable to view problems holistically. In other words they could not integrate parts of a problem to form the whole, nor could they break the whole into its individual parts. This was especially true for part two on exams. For example, for part two on exam three students were asked to determine how the addition of different springs affected the simple harmonic motion of the spring. Most students determined the spring constant of a single spring and then added a second spring in series to determine the effects of the second spring on the spring constant. Not one student group thought to examine how springs added in parallel would affect the system. They were unable to see the big picture and could only focus on one part.

The inability to integrate concepts, i.e. seeing the big picture, was also evident on certain test questions and during repecharge. An example can be provided from test four. Students were asked to determine the amount of work done on a block by the force of friction. Most students correctly solved the problem in calories, however they failed to convert calories to joules, which was unit required in the answer.

It was also evident from repecharge that students have difficulties examining questions as a sum of many parts. As part of their repecharge, one group was asked to determine the X and Y components of velocity and acceleration for a ball that had been tossed up into the air at the marked points for the following situation:



Students in the group had an extremely difficult time determining what to do. After about twenty minutes they asked for help. The following chart was provided:

	Acceleration		Velocity	
	X	Y	X	Y
A				
B				
C				

Students still had difficulty and again asked for help. The question was then posed: "If you needed to calculate each of these what equation(s) would you use?". The group was then able to fill in the chart.

Another example comes from repecharge for test four. Several student groups were given the following problem:

> A homeowner is trying to decide whether he should insulate with twelve inches of wood or four inches of styrofoam. Which would you suggest and why?

Most students suggested that the homeowner insulate with the styrofoam because it had lower thermal conductivity and was therefore a better insulator. When they were asked if the thickness of the insulator played a role in their choice many indicated they had not taken that into consideration. They were asked to then also take the thickness of the insulator into consideration and more fully explain which insulator they would choose and why.

In summary there were three major problems 3 Rs students had in learning mechanics. These were: a) solving problems that involved using a diagram to obtain information; b) reading and understanding graphs; and c) viewing problems holistically.

Conceptual Change

According to the theoretical model, students who work in cooperative groups (the social environment) and use materials that scientists use (physical environment) and work with an instructor who assumes the role of the facilitator of instruction would be more likely to undergo conceptual change as identified in path four of Appleton's model. There was little evidence to support the assumption that working in cooperative groups had any effects at all on cognition. In fact, most students in the Three R's course tended to work individually dividing labor so that they could finish as soon as possible. Often, for part two of exams one person would do most of the work. Many students began to report other members of their group who did not pull their own weight.

The instructors in the course felt most conceptual change and understanding occurred during instructor probing. The only evidence for this was anecdotal.

Attitude Toward Science

The fourteen questions from the Attitude Toward Science instrument were administered to students in both sections during the second week of the fall semester. Questions that were positively worded (e.g. Science is fun.) were assigned five points for an answer of "strongly agree", four points for an answer of " agree", three points for a neutral response, two points for an answer of "disagree", and one point for an answer of " strongly disagree". Items that were negatively worded (e.g. When I hear the word science I have a feeling of dislike.) were reverse scored: "strongly agree" was assigned one point; "agree" was assigned two points; "neutral" was assigned three points;

"disagree" was assigned four points; and "strongly disagree" was assigned five points. The maximum possible score was a 70, indicating a very positive attitude toward science. The minimum possible score was a 14 indicating a very poor attitude toward science. Students with a completely neutral attitude toward science would receive a score of 42. Items left blank were coded as a neutral response.

The mean pretest score for the Three R's section was a 58.34. The range of scores was a maximum score of 70 and a minimum of 33. The mean for the lecture section was a 57.48. The range of scores was a maximum of 70 and a minimum score of 40. In order to determine if there were any differences between the pretest scores for the two groups a t test procedure was conducted. First, an unequal variance F test was conducted to determine which t test procedure should be used. The F statistic was found to be 2.26. This was not significant at the .05 level and it was determined that the variances were equal. An equal variance t test was conducted and the test statistic was determined to be $.3310_{1df}$. This statistic was not significant at the .10 level and it was therefore determined that there was no difference in the two pretest scores.

The fourteen questions were then divided into two groups based on the type of question; attitude toward the subject science and attitude toward the study of science. There were no significant differences in any of the subset scores. The mean score for attitude toward subject science for the Three R's was 37.42. The mean score for the lecture section was 36.90. In order to identify significant differences between the two groups a t test procedure was conducted. An equal variance F statistic was calculated to determine which t test procedure to use. The F statistic was found to be 1.95 which was not significant at the .05 level. An equal variance t test then was conducted and the test statistic was determined to be $.3224_{1df}$. This was also not significant at the .10 level and it was therefore determined that there was no difference in the attitude toward the subject science scores between the two groups.

The mean score for attitude toward study of science for the Three R's was 20.95. The mean score for the lecture section was 20.58. In order to identify if the differences in the two groups' scores were significant a t test procedure was used. In order to determine which t test procedure should be used an equal variance F test was conducted. An equal variance F statistic was calculated to be 3.16. This was found to be significant at the .05 level and it was determined that the variances were unequal. An unequal variance t test was conducted and a test statistic of $.3564_{1df}$ was calculated. This statistic was not significant and it was determined that there was no difference in attitude toward study of science scores between the two groups.

The posttest was given to both groups the last week of the fall semester. The mean posttest score for the Three R's was 57.68. The maximum score was a 70. The minimum score was a 32. The mean posttest score for the lecture section was a 56.27. The maximum score was a 70 and the minimum score was a 42. In order to determine if the difference between the two groups' scored were significantly different a t test procedure was used. Again an equal variance F statistic was calculated for the two groups in order to determine which t test should be used. The F statistic was determined to be 1.10. Since this was not significant at the .05 level it was determined that the variances were equal. An equal variance t test procedure was conducted and a test statistic of $.506_{1df}$ was calculated. This statistic was not significant at the .10 level and it was therefore determined that there was no difference in the posttest scores for the two groups.

Once again the test questions were divided into two groups based on the type of question: attitude toward subject science and attitude toward the study of science. Again, there were no significant differences in these subset scores. The mean test score for attitude toward subject science for the Three R's was 37.26. The mean test score for the lecture section was 35.56. In order to determined if the differences in the two groups scores were significant a t test procedure was used. An equal variance F statistic was calculated to determine which t test should be used. The F statistic was calculated to be 1.29. This was not significant at the .05 level and it was determined that the variances for the two groups were equal. An equal variance t statistic was then calculated to be $.845_{1df}$ which was not significant at the .10 level. The mean test score for attitude toward the study of science for the 3 Rs was 21.47. The mean score for the lecture section was 20.00. A t test procedure was then used to determine if the differences in the two groups scores were significant. An equal variance F test was conducted and the F statistic was determined to be 1.29. This was not significant at the .05 level and it was determined that the variances were equal. An equal variance t test was conducted and the test statistic was determined to be 1.31_{1df}. This was not significant at the .10 level and it was determined that there was no difference in the attitude toward the study of science test scores for the two groups.

In order to determine if there were significant differences in the pretest and posttest scores for each group a gain score was calculated and a t test procedure was conducted for each gain score. The mean gain score for all fourteen question for the 3 Rs group was -.684. The mean gain score for the lecture section was -1.28. An equal variance F statistic was calculated to determine which t test procedure should be used. The F statistic was determined to be 5.24. This was significant at the .05 level. An unequal variance t statistic was calculated and was found to be $.302_{1df}$. This was not significant at the .10 level and it was determined there was no difference in the total gain scores for the two groups.

A gain score for each subgroup of test questions was then calculated. The gain score mean for attitude toward subject science for the 3 Rs was determined to be -.158. The mean gain score for the lecture section was -1.414. An equal variance test statistic was calculated to determine which t test procedure should be used. The F statistic was found to be 8.20. Since this was significant at the .05 level an unequal variance t statistic was calculated. The test statistic was determined to be $.883_{1df}$. This was not significant at the .10 level and it was therefore determined that there was no difference in the gain scores between the two groups for attitude toward subject science.

The mean gain score for attitude toward study of science was found to be .53 for the 3 Rs section and -.57 for the lecture section. Again an equal variance F statistic was calculated to determine which t test procedure should be used. The F statistic was found to be 1.17. Since this was not significant at the .05 level an equal variance t test procedure was used to calculate a t statistic. The test statistic was determined to be 1.08_{1df} which was not significant at the .10 level. It was therefore determined that there was no difference in the two groups test scores. See Tables 7, 8, and 9 for a summary of attitude scores.

Table 7
Attitude scores

	Pretest	Posttest	Gain
3 Rs	58.34	57.68	-.684
(SD)	(10.27)	(9.84)	(4.06)
Lecture	57.48	56.27	-1.28
(SD)	(6.82)	(9.37)	(9.28)
F statistic (30,20)	2.26	1.10	5.24*
t statistic (1)	.331	.506	.302

*Significant at the .05 level

Table 8
Attitude Toward Subject Science

	Pretest	Posttest	Gain
3 Rs	37.42	37.26	-.158
(SD)	(6.57)	(4.41)	(2.46)
Lecture	36.9	35.56	-1.41
(SD)	(4.70)	(3.43)	(7.03)
F statistic (30,20)	1.95	1.29	8.20*
t statistic (1)	.322	.845	.883

*Significant at the .05 level

Table 9
Attitude Toward Study of Science

	Pretest	Posttest	Gain
3 Rs	20.95	21.47	.53
(SD)	(4.00)	(4.41)	(3.67)
Lecture	20.58	20.00	-.57
(SD)	(2.26)	(3.43)	(3.40)
F statistic (30,20)	3.16*	1.29	1.17†
t statistic (1)	.356	1.31	1.08

*Significant at the .05 level

Interviews

The interview data also suggested there were basically no differences in the two groups' attitudes toward science. No students in either section felt that the course they were enrolled in had influenced their career choice. Most indicated their career choice had influenced their decision to enroll in their physics course. Most students also indicated that the course in which they were enrolled had not influenced their decision to enroll in other science courses. Only one student in the 3 Rs group, Mary, felt the course had influenced her decision to enroll in other science courses. When Mary was asked, "Has this course in any way influenced your decision to enroll in other science courses?", she replied:

> "Oh gosh, yes. The other day I was thinking I was ready for an electrician course. From my design background, the interest has always been there. I used to fear electricity. Now I feel it's fear from unknowing. Now I feel like I have more of an understanding...I have more desire to take classes that I had no desire to before."

When students in the 3 Rs were asked to describe their experience in their physics course last semester, several students commented on the structure of the course. Students had mixed opinions on how the course was structured. Many students felt they needed more structure in the course. For example, one student, Jennifer, said:

> "I feel like, maybe, for me personally I need more structure. I need to have someone explaining things more from the book. It's like a new math homework problem. Then I come in and do the lab. And like they tell me just get to work. I sometimes feel kinda lost about not bringing information from the book into the lab. I need help getting it together and everything."

Other students, however, indicated they really enjoyed the format of the class. For example, Lisa indicated the structure of the course helped her learn:

> "I've been able to do well in this class. I feel like I've been more in control. It's not really easier, but you understand it more because you have more help and it's a little more open. You have two helpers in the class. If you ask a question you don't really feel stupid...(It's like) you work under contract. If you want to stay after and finish you have a certain deadline (by which to finish). You can do it at your own speed. I like that you do it at your own pace."

Another student, Alice, also felt the structure of the course better suited her learning style:

> " I think (this class) is a very good idea, because it's more individualized. You're not sitting in a big lecture class and coming in and taking quizzes. And I like using the computers."

The theoretical model adopted for this study suggested that a constructivist environment would influence student attitude toward science. It was hypothesized that students would like science better, i.e., have more positive attitudes toward science if constructivist practices were used. The interview data provides some insight on this subject. Students in both sections identified practices that were decidedly constructivist as the most enjoyable aspects of the course . Several students enrolled in the lecture course indicated they liked the demonstrations and interaction with the professor. One male student, Andy, said:

> "This is the second experience in physics for me. It's been a positive experience. I have learned a lot more the second time around...(In the course I am in now) there is more interaction with the professor."

A female student, Cindy, also identified a constructivist practice as influencing her attitude toward the course. In her words:

> "I was really dreading physics. I had an expectation. I was just taking it because I had to. It's a requirement. It's really been much more positive than I expected it to be. I enjoyed the class very much. Some days I hate physics because it's a challenge. Some days I love it because it's interesting. (The professor) does a great job making conceptual ideas in physics applicable to real life."

A third student, Becky, in the lecture section identified demonstrations and hands-on activities as an enjoyable part of the course:

> " I like the demonstrations. They were extremely helpful in helping me understand the material. The hands-on stuff you can really see what is happening."

The Three R's students also indicated they enjoyed the hands-on experiences. Two of the interviewees, Mary and Sandra, exemplified the tone of the 3 Rs students:

> Mary: " I like (the 3 Rs course) a lot better because this is hands-on. The lecture class is just lecture. In (my other science classes) the lab was separate than the class. And then that wasn't productive. I think the one thing about having this class, the lab and the lecture together, you have the same people, the same person knows what's going on."

> Sandra: "I really liked the hands-on experience. I was a little skeptical at first. I didn't know what to expect. It was something new. It was easier than I thought. It has been better than any of my other (science) courses. It is a lot more work, but I would recommend it. I've always enjoyed labs. Its the other work I don't like because I get bored. I felt like I was doing real science because of the thought process, what would work, what wouldn't work, and seeing how the math really fit in. This is more in depth."

Other students in the 3 Rs course also felt they were doing real science. When asked "Do you feel like you were doing real science? In other words, do you feel like you did things real scientists do?" Mary was very explicit in why she felt she was doing real science:

> "Oh yeah. Definitely. Especially when we run trials. We have more than one trial to show the variance. I've had some statistical work... It was interesting to see how far off (our values) were from the mean. That's interesting because I can go to a science manual or journal and see the data tables or graphs, and know what really went into it. No, I didn't do that whole thing, but at least a tiny potion of what they had to do...And I guess when a lab was confusing it's even more like science because we have a manual. Scientists that are working on a specific project don't have manuals, they have unknowns. All they have is a certain procedure to follow. They know if they can repeat it and get the same answers through trials then they know they're on the right course. I think our lab is like that. Real science isn't a few lectures and do a few projects with one topic. A lab usually takes one topic and has three hours (to cover that topic). You miss a lot. At least here, every single section we are dealing with we have lab..."

The lecture section students did not believe they were doing real science. Cindy's response to the question was adamant:

> "Oh gosh, no. The lab materials are so archaic compared to other science courses I have been in. We don't even have a decent balance. We have to use these crummy little beam balances that you pile up the weights and they are totally inaccurate. I think in a real lab it's a little more sophisticated. I realize in a science lab of course, they are going to have more advanced instrumentation."

Andy also felt the labs did not emulate the practices of scientists:

> "I think (our labs were giving us the) basic idea...real science to me is when you are actually applying what you have learned. Applying science to the real world. The labs we did required no follow-up experiment and no thought. That's not real science..."

Students were also asked, in general, what role they felt women should play in the sciences. All students indicated that women should play the same roles as men do. The men did not chose to elaborate on this question, however most of the women did. Sandra, a 3 Rs student, elaborated on her previous experiences in science classes and how she chose to deal with her expected role and the men in her classes:

> "I think women should not be intimidated by (science). I think teachers might sometimes deter you. They might pick Joe over here instead of Sally to answer a question. I don't know if I ever went through that anyway (teacher determent). I might know the answer to the question, so I just nose my way in. If they did call on a boy and they didn't know the answer, (even though) I didn't want to intimidate the male species (laughs), I (would) jump right in with the answer."

Another woman in the Three R's, Andrea, course had this to say:

> I think a lot of women are intimidated by (science) because like science seems like a man's field".

A lecture section students, Becky, also felt intimidated by the course and the number of men in the course. When she was asked about enrolling in physics, she said:

> "... I was intimidated by (the class) because there were more guys in this class than any other class. This was physics. Hard science..."

Cindy, also in the lecture section, also had been led to believe that science was a male-oriented career. She explains her reflections of why in high school and in her first degree program she chose not to major in science:

> "I think women should be as free as men to pursue the sciences. It's tough because I don't think they are because of the way we are taught in this culture. The society has said that women should not be scientists. I feel that's influenced my life because as a high school student I never

> took anything beyond the basic requirements. I look back and the only reason I can figure out why that I didn't pursue the courses that I enjoy is because I felt like I wasn't suppose to like it. Now that I am at the college level, I've gone out into the world and worked, whatever. And coming back to school I am taking science at the college level and am planning to pursue it further. I am enjoying it very much and I am doing just as well as ever. That makes me say that women should be able to play any role as scientist as they want. At the other end of that question, I think one problem that has been shown to have occurred with a lot of scientists' experimentation is that they tend to consider men and extrapolate that to the entire human population. Which is really not the case. Experimentation on females should be considered separate experimentation and should be pursued as much as experimentation on men."

Two women in the 3 Rs course indicated that they also knew women who felt the same way the previous interviewee felt. Lisa's comment was very similar to Cindy's. She said:

> "I think women's role in science is important, because women can do science like men can do. I've never thought of myself as not being able to do science. But often girls say they're not able. They don't think of themselves as not able to do science. But they have some all women's classes in high school and the girls do better because they don't have they guys to distract them. Like the guys aren't scared to ask questions."

Several of the women enrolled in these courses did indicate that the course did change their attitude toward science. Becky, the woman in the lecture section who liked the demonstrations and the hands-on aspects of the lecture course and who indicated she was intimidated by the number of men in the course, said:

> "(As) I began to understand it I became much more confident...It's made me feel better about my future classes...This class has helped me realize I've made the right decision (in choosing science as a career)."

Lisa, a 3 Rs student, had this response when asked if the course had influenced her career choice:

> "I guess you can say it has. I've been able to do well in this class. I feel like I am more in control."

Students in the 3 Rs course commented on how they felt this method of teaching affected their learning of the material. Mary felt she learned more by using hands-on materials:

> "The learning is not forced...This hands-on stuff is being stored in long term memory. It's not just reading it and forgetting it..."

Jennifer, another 3 Rs student, felt the approach to teaching was more applicable to everyday life than a physics lecture course she had been in previously:

> "Some things I realize I am understanding, but I really wonder just how much. But then again when you are forced to memorize it all you're really not learning it... I was in a previous physics class (the lecture course). And it was more abstract. And this process I like it much more because it seems applicable to real life situations. (Now) I understand. Before (in the other class) in was like whoa. Real life doesn't deal like that."

Mary also commented on how important she felt the role of the instructor was in helping students understand the material:

> "The instructor adds to the class a great deal. The manual will show you a diagram, but it doesn't give you the procedure how to get to that point, and that's where the person comes into play. We definitely need that."

In summary the interviews supported the quantitative findings. There basically were no differences between the two groups attitudes. The qualities both groups said they liked most about the courses were decidedly constructivist; the hands-on activities, demonstrations, and applications to everyday life. Many of the women felt there were societal pressures exerted on them to not major in science. They also believed physics was a 'hard science'; a science that was for men. Many of the women also felt that because they had been successful in these courses they were more confident in their choice to pursue a career in science.

The students in the Three R's course felt they were emulating the practices of scientists in the classroom. Students in the lecture section did not share this belief. Many felt their labs were disorganized and archaic.

Fitting the Data to the Model

The theoretical model, the Constructivist Learning Model, on which this study was based suggests that student background knowledge and experience affect cognition. Ideally, an Analysis of Covariance test would be conducted using a variable such as SAT score to serve as the background covariant with the section students were enrolled in to determine if there were any significant differences in Mechanics Baseline scores. Unfortunately one of the fundamental assumptions, independent observation of Baseline scores, was not meet. Therefore, this assumption can not be examined using a statistical test.

In order to examine this assumption, self-reported SAT scores and grade point averages were examined. The mean self-reported SAT score for students in the Three R's course was 1028. The median SAT score for the

Three R was 950. The mean self-reported SAT score for students in the lecture section was 1148. The median self-reported SAT score for students in the lecture section was 1230. Students in the 3 Rs section had an average GPA of 3.0. Students enrolled in the lecture section had an average GPA of 3.40. (See Table 10).

Table 10

Self-reported SAT Scores and GPA

	SAT		Mean GPA
	Mean	Median	
3 Rs	1028	950	3.0
Lecture	1148	1230	3.4

*Not all students had taken the SAT. Many indicated they had taken the ACT. (3 Rs n=12, Lecture n=18)

This data suggests that students in the lecture section are more successful in college and were better prepared for college than those in the 3 Rs course. However, students in the 3 Rs course did just as well on the *Mechanics Baseline Test.* Research suggests that a predominately non minority male group should outperform a predominately female group on cognitive tests in the physical sciences(Grossman & Grossman, 1994; Kahle & Meece, 1994). This was not the case in this study.

The model also suggested that a constructivist learning environment would influence student attitudes toward science. The *Attitude Toward Science in School Assessment* scores did not indicate there was any change in attitude toward science. However, the qualitative interview data indicated that women enrolled in these courses felt more confident because they were successful in the course. The quantitative findings are not surprising considering that students enrolled in these courses had very positive attitudes toward science at the beginning of the course. Since these scores were already high the only changes that could have been detected would have been lower scores indicating less positive attitudes toward science. The fact that students in these classes had such high attitude scores is also not surprising. Enrollment data at The University of North Carolina at Greensboro suggests that students who are non-science majors choose to enroll in the life sciences for their required lab science credit.

In general, the data collected for this study supports the theoretical framework. Women enrolled in a constructivist physics course perform just as well as predominately non-minority males in a lecture course. Overall, the women enrolled in the 3 Rs course had lower SAT scores and lower GPA's than students in the lecture course suggesting that the constructivist learning environment mediated their understanding of physics concepts.

The data also supports the hypothesis that use of constructivist learning strategies would affect student attitudes toward science. Students in both the lecture and 3 Rs course indicated hands-on activities, interaction with the instructor, and application to real life made physics more enjoyable. Enjoyment of science courses is an integral part of attitude toward science. Women in both courses felt more positive in regard to their career choice due to the successful experience they had in physics.

Archival data corroborates the findings for this study. Fifty-five percent of the students enrolled in the spring on 1993 indicated they had learned more in the 3 Rs course than other science courses. One student group indicated they felt that the "class had a positive impact on (their) ability to actually do science instead of just learn science...". Eighty-three percent of the students enrolled in the 3 Rs course in the Spring of 1994 indicated they felt the hands-on approach to learning physics had positive effects on their learning. One student group wrote the following statement in their course evaluation:

> "The entire set-up of the program allows a student to experience physics from a hands-on point of view. This is important because the idea of learning physics from a book is very frightening...One can get through a lecture course in physics by memorizing certain formulas and never knowing how or why they apply to certain situations. That path is impossible with the 3 Rs procedure. It is necessary that students have a full understanding."

Fifty percent of the students enrolled in the Spring of 1994 and twenty-seven percent of the students fro the Spring of 1993 indicated that the 3 Rs course had in some way influenced their career choice. Most of these students indicated the course had boosted their confidence in their ability to do well in science courses.

The *Mechanics Baseline Test* results for the Fall semester of 1992 also supports there was no difference in scores on the tests for the 3 Rs course and the lecture course. The mean number correct for the *Mechanics Baseline Test* for the Fall of 1992 was 6.47 (n=30; SD=2.34). These scores are very similar to those obtained for this study. Unfortunately there are no lecture section group equivalent scores for Fall 1992.

CHAPTER V

DISCUSSIONS, CONCLUSIONS, AND RECOMMENDATIONS

Discussions

The purpose of this study was to examine the effects on the restructured pedagogy of the 3 Rs course on student cognition and attitude toward science. The lecture course was used as a comparison to determine these effects. Statistically, there were no differences in the two groups. However, qualitative data suggested that several differences did exist between these groups.

First, the data collected for this study indicates that students in the 3 Rs course could not interpret diagrams as well as students in the lecture course. In particular students in the 3 Rs course had more difficulty with force diagrams. The theoretical model for study indicated that in order for students to understand certain concepts they should be provided with the opportunity to act on objects as do physicists. Unfortunately for many concepts there are no concrete or visual activities in which students are able to experience phenomena. For example, there is no way to 'see' forces. In the activities 3 Rs students participated in to study force, they used a force probe to hang objects from and move a dynamics cart. The students did not get very good results from using the force probes. As a result they had a difficult time understanding how hanging and moving objects was related to force. The students did not have any activity that was designed to identify normal forces.

Perhaps the fact that they could not 'see' these forces explains why they did not understand force diagrams. The lecture section students had more opportunities to draw force diagrams than did the 3 Rs students. The theoretical model also suggests that a students background knowledge and experience also play a role in their conceptual understanding. If one accepts this model, these results are not surprising considering students in the lecture course had a median SAT score that was 280 points higher than the median SAT score for the 3 Rs.

Secondly, the data indicated that the 3 Rs students had problems reading and interpreting graphs. The interview results indicated that the 3 Rs students were beginning to correct this problem. In the interviews the 3 Rs students were more successful than the lecture section students at drawing an acceleration graph from a velocity graph. Neither section was particularly successful at drawing a force graph from a velocity graph. Perhaps this is because the 3 Rs students had the opportunity to 'see' velocity and acceleration in their activities. They moved toward or away from a motion detector that immediately showed them a graph of their motion. When 3 Rs students were first asked to draw velocity graphs from acceleration graphs and visa versa they were not successful at doing so. This continued experience helped students to be able to visualize these graphs..

Graphs and diagrams play a crucial role in how scientists communicate their findings. Since language is symbolic representation used for communication, graphs and diagrams can be considered as the language of scientists. According to the model, language plays an important role in facilitation of student understanding. The 3 Rs students had not yet mastered this new language by the end of the semester.

Thirdly, the data indicated that students in the 3 Rs course had trouble viewing problems holistically. This is one area of scientific literacy that Rutherford and Ahlgren (1990) have deemed a part of scientific habits of mind. They believe every American should posses critical response skills that allow them to be able to apply critical skills to their own observations, arguments, and conclusions. Students in the 3 Rs course had not mastered these skills by the end of the semester.

The quantitative data provided no supportive evidence for detecting differences in student attitudes toward science. The fact that students in both sections had very positive attitudes toward science coming into these courses made it difficult to detect any positive changes in student attitudes. The only differences that could have been detected with a group this small in number would have been more negative attitudes toward science. Students attitudes did not become more negative. In the interviews, students said the parts of the courses they enjoyed the most were constructivist in nature. These included hands-on activities, instructor interaction, and real life applications.

The women interviewed from both groups said they felt much more confident about their career choice because they had been successful in their physics courses. They also made comments about how they or other women they knew felt intimidated by science, physics in particular, because it was a 'man's field'. These comments are particularly important because they were unsolicited and made by several of the female interviewees. This is supportive evidence that women enter physics courses with existing beliefs about women in science. The fact that they feel more confident after a successful experience in science courses that used constructivist strategies to teach content also is supportive evidence for the theoretical model of improving women's attitude toward science by implementing certain constructivist strategies. In the case of this study it was the use of hands-on activities, instructor interaction, and applications to everyday life.

However, it should be pointed out that the definition of 'hands-on' activities is different for these two groups. For the lecture section 'hands-on' activities were demonstrations conducted by the instructor. In the 3 Rs 'hands-on' activities were the activities in which the students *participated.* It was interesting that not one of the lecture section students who were interviewed mentioned how they felt the lecture helped or hindered their learning. Lisa, Mary, and Jennifer from the 3 R's course all felt the course helped them really *learn* the material. There has been little research conducted on how demonstrations affect student understanding of physical phenomena. Preliminary research conducted by Krauss et al., (1994) suggests that demonstrations are relatively ineffective for long term memory storage. It is an area that merits much further study.

Conclusions

Based on these data the following conclusions can be drawn:

1. Student enjoy science classes more if certain constructivist strategies are used, i.e., hands-on activities, instructor interaction, and applications to everyday life.

2. Women feel more confident about their science career choice if they are successful in their science courses;

3. Students who are not as well prepared can match an understanding level of better prepared students when exposed to a constructivist leaning environment;

4. In order for students to be highly successful in their science courses they must understand the language of scientists, more specifically they must be able to comprehend graphs and diagrams.

None of these conclusions are surprising. The conclusion that student enjoy science classes more if certain constructivist strategies are used has already been reported by Ebenezer and Zoller (1993). A study conducted by Rosenquest and McDermott (1987) reported the similar result that students could reach a higher level of understanding of kinematics concepts after exposure to instruction constructivist in nature. Recently science educators have become particularly interested in the role language and dialogue play in student understanding (Fischer & Von Aufschnaiter, 1993; Glasson & Lalik, 1993). The findings that student understanding is impeded by not understanding the language scientists use to explain data, i.e. graphs and diagrams, also is not surprising. Use and mastery of language in the science classroom is another area that merits much further research.

A third area that merits much further research is the idea that women and perhaps minorities can be further encouraged to enter science professions by using teaching strategies that allows them to be more successful in science courses thus affecting their attitude toward science. In this particular study use of constructivist strategies such as hands-on activities, instructor interaction, and applications to everyday life affected student attitudes. Other studies have identified working in cooperative groups with other females as having positive effects on women's learning (Andrews & Meisner, 1994; Belenky et al., 1986). It would be interesting to develop a year long case study that examines all these factors.

Recommendations

It is difficult to draw conclusions about career choice in such a short time period. In order to determine if using certain teaching techniques and practices are to truly influence women and minorities to pursue careers in science, a longitudinal study needs to be conducted. The 3 Rs project is just completing its third year. It would be especially enlightening to interview students from the previous two years to ascertain the effects of this course after at least one year has passed. These students should be contacted again several years in the future.

Several findings in this study should be particularly interesting to secondary science teachers. The finding from this study suggests that high schools are not spending enough time developing scientific habits of mind nor are they facilitating scientific language development. Science educators have already begun reform movements in science education to create a more scientifically literate society, a society that has acquired the ability to think critically and one that views science more favorably and more intelligently. A specific example of this reform is in North Carolina. State competency goals and objectives are no longer emphasizing the memorization of vast amounts of information. Instead, teachers are encouraged to facilitate science process skills. These skills encompass the ability to interpret data, which includes interpreting graphs and diagrams. These skills, if taught properly, should also help student be able to view problems holistically. In other words students should acquire scientific habits of mind.

These competency goals also intend to foster positive attitudes toward science. Teachers should be encouraged to use and coached on how to use hands-on activities to promote student understanding of science concepts. Based on the results of this study, if the afore mentioned and other constructivist strategies are used to teach science students will begin to view science more intelligently and more favorably. If these broad general goals are meet then perhaps more women and minorities will choose to have science and science related careers.

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Appendix A

Physics 101
Fall, 1994
Class: MWF 1:00 - 1:50
Text: *Physics* by D.C. Giancoli

Dr. Frank McCormack
Office: Room 104

Date		Text Chapter	Text Chapter or Lab
Mon. Aug	22	1	
Wed.	24	2	2
Thur.	25		2
Fri.	26	2	
Mon. Aug.	29	2	
Wed.	31	3	3
Thur. Sept.	1	3	3
Fri.	2	3	
Mon.	5	No Class	Velocity, Displacement, and Acceleration (M-3)
Wed.	7	4	
Fri.	9	4	
Mon.	12	4	
Wed.	14	4	4
Thur.	15		4
Fri.	16	4,5	
Mon.	19	5	Acceleration and Newton's 2nd Law (M-4)
Wed.	21	5	
Fri.	23	Test 1	
Mon.	26	6	Centripetal Force (M-104)
Wed.	28	6	
Fri.	30	6	
Mon. Oct.	3	6	
Wed.	5	7	7
Thur.	6		7
Fri.	7	7	
Mon.	10	7	Conservation of Momentum (M-6)
Wed.	12	8	
Fri.	14	8	
Mon.	17	No Class	
Wed.	19	8	9
Thur.	20		9
Fri.	21	9	
Mon.	24	10	Archimedes' Principle (M-59)
Wed.	26	10	
Thur.	27		
Fri.	28	10	

Mon.	31	10	
Wed. Nov.	2	11	11
Thur		11	11
Fri.	4	11	
Mon.	7	12	Speed of Sound (S-5)
Wed.	9	12	
Fri.	11	Test II	
Mon.	14	13	
Wed.	16	13	13
Thur.	17		13,14
Fri.	18	13	
Mon.	21	14	No Lab
Wed.	23	No Class	
Fri.	25	No Class	
Mon.	28	14	Specific Heat (H-53A)
Wed.	30	14,15	
Fri. Dec.	2	15	
Mon.	5	Test III	No Lab
Wed.	7	Review	

The Final Exam is scheduled for Friday, December 9, 3:30 to 6:30.

Attendance at each Laboratory session and each scheduled test is mandatory. The date on which the tests are scheduled is firm. No test will be given early. Make-up tests may be given at the instructor's discretion in cases of illness or death in the immediate family. Make-up tests will not be given unless permission to be absent is granted by the instructor before the test begins. A missed test automatically counts as zero credit. The grade for the course will be determined as follows: Lab 16%, Homework 16%, Hourly Tests 16% each, Final Exam 20%. The final exam will be comprehensive.

3 Rs Syllabus, Physics 101-01 Fall 1994

Text: Physics by Cutnell & Johnson, 3rd Edition. Available UNCG Bookstore or Addams Book Store (Tate St)

Date	Activity Unit & Text Chapter	Topic	Text Chapter	HW Text Questions	HW Text Problems	Due Date HW
Aug 22	1	Introduction to Course	1.1-1.6	7.9.	6,7,13,14	Aug 29
24	1	and to Computing	1.7-1.8	11,13	23,34,37,45,46,60	Aug 29
26	2	1-D Motion	2.1-2.4	7,12	4,5,12,15,20,23,27	Sept 7
29	2		2.5-2.7	14	43,46,59,60,63	Sept 7
31	2					
Sept 2	3	2-D Motion	3.1-3.3	5,10	3,5,17,19,26,30	Sept 12
5		*Labor Day*				
7	3		3.4	14,16	50,53,56	Sept 12
9	3					
12	4	Forces	4.1-4.7	2,4,6,11	6,12,15,19,22,32	Setp 19
14	4		4.8-4.11	15,18,22	39,44,53,55,59	Sept 19
16	4		4.12		70,75,77,106	Sept 19
19	5	Circular Motion (SA)	5.1-5.4	5,7,	6,9,14,19	Setp 28
21	5		5.5-5.7	12,13,16	21,23,37,38,44	Sept 28
23	5	Unit 5 & Review Test 1				
26		Test 1 Chapters 1 - 4			Taken at Station	
28	6	Work & Energy	6.1-6.3	2,4	6,7,14,19,32	Oct 3
30	6	Test 1 Part II due 4 PM	6.4-6.8	16	38,39, 47,48,58,74	Oct 3
Oct 3	6					
5	7	Impulse & Momentum	7.1-7.2	1.6.	4,7,15,16,24	Oct 10
7	7		7.3-7.5	8,9,13	27,28,38,47	Oct 10
10	8	Rotational Kinematics	8.1-8.3	5,6	4,7,14,17	Oct 19
12	8		8.4-8.6	11	33,45,53,56	Oct 19
14	8					
17		*Fall Break*				
19	9	Rotational Dynamics & Review Test 2	9.1-9.3	6,7,10	2,6,11,17,22	Oct 21
21		Test 2 Chapters 5-8		Taken	Individually	
24	9		9.4-9.6	13,20,21	31,33,46,57,58,	Oct 31
26	9					
28	10	SHM / Part II due 4 PM	10.1-10.3	1,5	5,11,23,26	Oct 31
31	10		10.4-10.6	10,14,15	37,41,51,55,65,66	Nov 7
Nov 3	10					
5	11	Fluids	11.1-11.5	4,5,7,12	5,11,14,20,24,25,3 6	Nov 11
7	11		11.6-11.10	14,19,26	44,45,4959,60,64	Nov 11
9	11					
11		Catch up, Review Test 3				
14		Test 3 Chapters 9-11				

3 Rs Syllabus, Physics 101-01 Fall 1994

16	12	Temperature & Heat	12.1-12.4	7,8,12	2,11	Nov 21
18	12	Part II due 4 PM	12.6 - 12.8	20,22,23,28	43,47,60,63,72	Nov 21
21	13	Heat Transfer	13.1-13.3	4,7,8,10	6,9	Nov 28
23	13		13.4	12,14,22	26	Nov 28
25		Thanksgiving				
28	14	Demos, problems	14.1-14.3	3,4,7,10	2,15,18,32	Dec 5
30		Test 4 Chapters 12-14				
Dec 2	15	Thermodynamics	15.1-15.5	4,6,	4,13,26,37	Dec 5
5	15		15.6-15.10	16,21	46,56,64,75	not hand in
7		Work on Part II Final				
9		Part II due 4 PM Part I in class 12-3 PM	Final Exam 12 - 3 PM		Chap 1-15	

Attendance Policy

You are allowed 2 unexcused absences, realizing, of course, that you greatly burden you lab partner when you are absent. When you return to class, you are to continue where the rest of the class is, not where you left off. You must make up the work you missed *outside of class* . For each unexcused absence > 2, your grade will be lowered 4 points. After a total of 6 unexcused absences, you will be asked to kindly leave the class. Classes start on the hour. 10 minutes late for class may be regarded as an absence.

Other Protocols

HW is done outside of class time. You are encouraged to collaborate on HW, but need to hand in your own work, with your figuring and procedures. Class/lab work is a collaborative effort. When you hand in a 'formal' report, only one report need be handed in for each lab station. Likewise for Part 2 of exams.

Four exams are curved, if necessary. Repechârge is given within a week of the exam. Lowest exam grade is dropped.

Grading Procedure:

Class work..............................40%
Exams......................................25%
Final...15%
HW...15%
Quiz Average...........................5%
Class participation...................5%

PHYSICS & THE 3 RS Fall 1994

Monday 22 August, 1994

Welcome to *Physics & the 3 Rs,* a NSF-supported initiative whose purpose is to attempt to increase the number of underrepresented groups in the science and mathematics 'pipeline'. Today's schedule is:

- **Introductions:**

You, the class members, Sherri, former biology teacher and now doctoral candidate in the School of Education and your Graduate Assistant (GA); Anu Prabat, biophysicist and observer for the course; Harol Hoffman ,anthropologist and colleague with this project; and Jerry Meisner, physicist and instructor.

- **Discussion of the structure of the course:**

The course meets MWF from 10 AM until 11:50 AM. There is no additional scheduled lab.

'll briefly describe the difference between this course and Phy 101-91 which meets from 1-2 PM, MWF and has an additional 3 hour lab.

The good news about this style of learning is that the grades are higher in this course than in the 'regular' course with a lecture format (and, research has shown, you also learn a great deal more). The bad news is that you have to work hard to earn your grade. However, in this course, hard work nearly always translates into good grades. In the lecture course, hard work often translates into poor grades. The reasons for this are well understood.

- **Introduction to the Mac**

- **Activity 1-2 C.: Pitching Speed Data**

For the three distances in the table on page 1-4, use 10m, 20m and 30m.

- **Activity 1-2: D:**

Macintosh Basics 'application'is in the Macintosh Basics 'folder' on your Mac hard disk. We'll lead you through the beginning steps.

- **By Wed, 10 AM please**

  *** purchase and bring to class the <u>Activity Guide,</u> Physics 101-01, from the UNCG bookstore as well as the textbook.**

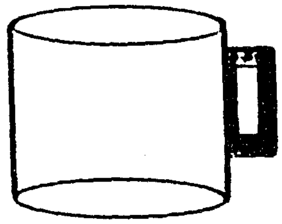
  *** finish through page 1-5 .** Room 201 will be open 8-5 PM or later for your convenience.

PHYSICS & THE 3 RS **Fall 1994**

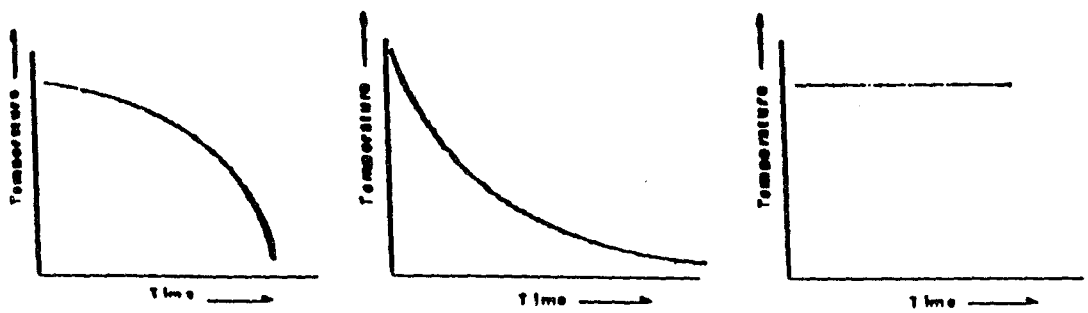
Concept Quiz #13 **NAME** ____________________

Closed book 10:00 - 10:15. If you finish before 10:15, please start on your other classwork.

1. Suppose you want a mug of hot chocolate to take to a soccer game on a cold fall day. Describe in detail the kind of cup you would use so that the chocolate would stay hot as long as possible. You may label various components of a cup shown in the schematic if you wish. You can add, subtract, or draw another mug, of course. Be complete.



2. Suppose you take that cup of hot chocolate and pour it into a well insulated bowl and measure its temperature with a temperature probe, taking the temperature of the chocolate at frequent intervals. You then plot the temperature vs. time. Which will be the most likely graph you will see ?



A B C

Explain why you chose what you did.

EXPERIMENT: Specific Heat and Heat of Fusion H53A

OBJECT: To determine the specific heat of a solid and the heat of fusion of ice.

APPARATUS: Water boiler, cast iron or brass specimen, beam balance with metric masses, thermometer, calorimeter.

DISCUSSION: The specific heat of a substance may be defined as the number of calories of heat required to raise the temperature of one gram of the substance one degree celsius. The calorie is so defined that the specific heat of water is unity. Almost every other common substance has a specific heat less than that of water. The specific heat of a substance may be determined by the METHOD OF MIXTURES wherein a known mass of the substance at a known temperature is mixed with a known mass of another substance (of known specific heat) at a known temperature, and the resultant temperature of the mixture is noted. The heat lost by the hot body equals the heat gained by the cold body. Since the heat transferred to or from the body of known specific heat can be calculated, the specific heat of the other body can be found. In Part A of this experiment a metal specimen is heated to the temperature of boiling water, then transferred to a cup of cold water. After a few minutes the temperature of the mixture becomes uniform as a result of the flow of heat from the hot specimen to the surrounding water and the cup. The heat lost by the specimen equals the heat gained by the water and the cup, and hence the specific heat of the metal can be calculated.

The latent heat of fusion is defined as the amount of heat per unit mass (cal/g) given up when a substance changes from the liquid state to solid state at the melting point. The latent heat is defined only at a phase transition point whereas the specific heat is defined at all points other than the phase transition points. In Part B of this experiment a few ice cubes are added to warm water. After a few minutes the resulting water mixture is at a new temperature lower than the original temperature but higher than the ice temperature (which we take to be $0^{o}C$).

PROCEDURE: (Read all temperatures within $0.1^{o}C$.)

PART A.

1. Half fill the boiler and start it heating.
2. Find the mass of the inner cup of the calorimeter (without plastic ring).
3. Find the mass of the metal specimen.
4. Lay the specimen on its side in the cup and add just enough water to cover it.
5. Remove the specimen from the cup and put it in boiling water for at least five minutes.
6. While the specimen is being heated add a few pieces of ice to the water in the cup to cool it about $10C^{o}$ below room temperature, find the mass of the cup with the water in it, and place it in the outer part of the calorimeter to minimize heat transfer through the walls of the cup. Stir the water until all the ice has melted.

7. When the specimen has been in the boiling water at least five minutes, read the temperature of the water in the cup, then quickly take the specimen from the boiler and lower it into the water in the cup. Be sure that the specimen is fully submerged, and brings with it very little water from the boiler.
8. Stir the water gently with the thermometer while watching the temperature. Record the maximum temperature reached, the final temperature of the mixture. (The temperature will first rise rapidly, then, after the specimen has cooled to the temperature of the water, will fall slowly due to the loss of heat to the surrounding air. Carefully watch the thermometer and note the highest temperature reached.)

PART B.

1. The latent heat of fusion is to be determined by putting a known mass of ice in warm water* whose mass and temperature are known. The heat lost by the warm water, calorimeter, and thermometer equals the heat required to melt the ice and raise the temperature of the water formed from the ice to the resulting temperature of the mixture. Read all temperatures within $0.1^{\circ}C$ and masses within 0.1 g.
2. Plan carefully the order in which you will proceed, listing the quantities you need to measure. Check your list and plans with the lab instructor.

*The heat transferred to and from the room is approximately "balanced out" when the starting temperature is as far above room temperature as the final temperature is below.

<u>CALCULATIONS</u>: The specific heat of the inner cup of the calorimeter is 0.217.

PART A.

1. Heat gained by cup and water = Heat given up by specimen. Since no phase changes occurred, $mc\Delta$is the expression for the heat gained or given up by each part. Find c for the specimen.
2. The specific heats of iron, brass, and aluminum are 0.113, 0.088, and 0.219, respectively. Which kind of metal was your specimen?
3. Find percent error for your value of c.

PART B.

1. Heat gained by melting ice and warming melted ice
   = Heat given up by warm water and cup.
   Some of these amounts of heat are given by $mc\Delta T$, but one is of the form mL, where L is what you are to find.
2. Find the percent error if the accepted value of L is 79.7cal/g.

ENERGY TRANSFER AND TEMPERATURE CHANGE

Investigation 3: Heating Other Materials

To find out

How transferring heat to liquids other than water affects the temperature change

The specific heat capacity of a liquid other than water

How to reach thermal equilibrium by balancing heat loss and heat gain

Materials

MacTemp or *PC-Temp* software
two temperature probes
heat pulser (relay box and heater)
Universal Laboratory Interface (ULI)
alcohol (isopropyl)
foam or other *insulated* cup
piece of metal with hole for temperature probe
boiling water
container marked in ml

Introduction

In Investigations 1 and 2 you examined how the temperature of a sample of water is changed by transferring heat to it, and you found the specific heat capacity of water. In this investigation you will use the same procedures to heat another liquid and find its specific heat capacity.

You will also measure the total heat lost by a hot object is placed in cooler water and the total heat gained by the water as they come to thermal equilibrium.

Activity 1 Heating a Liquid Other Than Water

1. Choose a liquid and record its name and mass density.

Name of liquid: ____________ Mass density: ________gram/ml

Prediction

Do you think it will take the same amount of heat energy (same number of pulses) to raise the temperature of this liquid the same number of degrees as an equal mass of water? Explain why you made this prediction.

____

____

2. Use *MacTemp* or *PC-Temp* to make the measurements that are needed to fill in the table on the next page just as you did when you used 150 grams of water. However, this time use 150 grams of your liquid and try to produce the same temperature rise as in Investigation 1, Activity 2. (Come as close as you are able.)

If you measure the liquid's volume instead of its mass, you will need to calculate the number of ml of the liquid that have a mass of 150 grams:

Volume of liquid: _______ml.

Desired temperature increase: _______°C

Initial temperature of liquid: _______°C

Desired final temperature: _______°C

Mass of Liquid (g)	Number of Heat Pulses	Change in Temp. (°C)	Temp. Change Per Pulse (°C/pulse)
150			

3. Compare your measurements to the results for water. Did it take fewer, about the same, or more pulses to raise this liquid's temperature the same amount as an equal mass of water? Did this agree with your prediction?

____

____

4. Calculate the specific heat capacity of the liquid. Use the mass of the liquid, the temperature change, the number of pulses, the length of the pulses and the calibration of the heater from Investigation 1, Activity 3 to calculate the specific heat of the liquid. Show your calculations below.

Specific heat of the liquid: _______cal/gram°C

Questions

How does your measured value of the specific heat of the liquid agree with the accepted value in your textbook or a handbook? By what percentage do the values differ? (Q1)

____

Did your measured value come out too small or too large? Explain why you think it came out this way. (Q2)

____

____

Using the accepted value for the mechanical equivalent of heat, calculate the specific heat of your liquid in joules/gram°C. (Q3)

____

Activity 2 **Heat Gain and Loss--Thermal Equilibrium**

In this activity you will examine heat flows from one object to another when a hot and a cold object are brought in contact with each other by observing temperature changes. You have already observed what characterizes the state of *thermal equilibrium* between the two objects--when they reach a common, steady temperature, and when there is no longer a net heat flow between them.

Prediction Record below the specific heat of water and the mass and specific heat of the metal you will be using in this investigation.

Specific heat of water:__________ joules/gram°C

Name of metal:____________________ Mass:______grams

Specific heat:_________joules/gram°C

If you heat the metal to a high temperature and put it into an equal mass of cool water at room temperature, will the final temperature be midway between the cool water temperature and the high temperature, closer to the cool water temperature or closer to the original high temperature of the metal? Explain how you decided what to predict.

____

____

____

Now test your prediction.

1. Prepare the temperature probes and software. Plug in two temperature probes. Display and graph both probes (Temperature 1 & 2). Set the time axis to 120 seconds and the temperature axis from 10°C to 110 °C.

2. Heat the metal and measure its temperature. Place probe 2 in the hole in the metal, and tape it in place. Place the metal in boiling water so that it is completely immersed.

3. Set up the water and get ready to graph. Pour a mass of cool water equal to the mass of the metal into a foam cup. Put probe 1 in the cup.

4. Start graphing *Stir the water constantly.* After 10 seconds, record the temperature of the water and the temperature of the metal.

   Initial temperature of the water:________°C

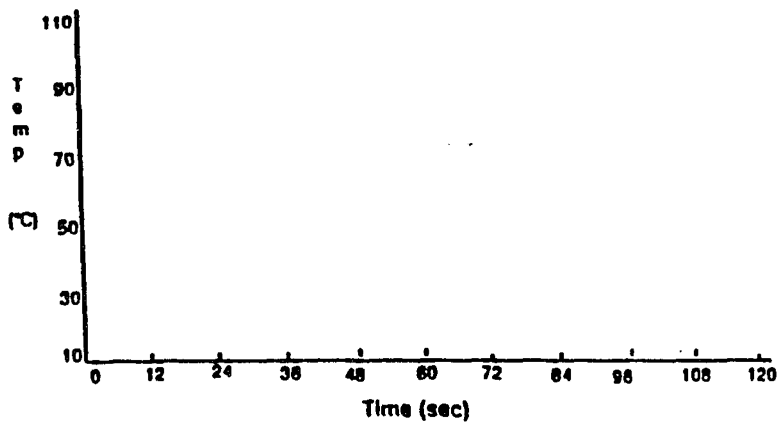
   Initial temperature of the metal:________°C

5. Quickly lift the metal out of the boiling water and place it into the cool water.

   Keep stirring. After the temperature stops changing, record the final temperature of the water with probe 1 and the metal with probe 2..

   Final temperature of water and metal:________°C

6. Sketch the graphs on the axes below.



7. Calculate the heat transferred to the water in warming up. Use the mass, specific heat and temperature change to calculate the heat transferred to the water. Show your calculations.

Heat gained by the water:__________Joules

8. Calculate the heat heat transferred from the metal in cooling down. Use the mass, specific heat and temperature change to calculate the heat transferred from the metal. Show your calculations.

Heat lost by the metal:__________Joules

Questions

Explain the shapes of your graphs based on what you know about heat flow and thermal equilibrium. (O4)

____

____

After you mixed the metal and the water together, what happened to the temperature of the water? What happened to the temperature of the metal? (O5)

____

____

Did the final temperature agree with your prediction? If not, can you explai why your prediction was incorrect? (Q6)

____

____

Does the heat gained by the water equal the heat lost by the metal? If not, what is the percent difference between them? (Q7)

____

____

What are the limitations in this experiment which might explain any differences in Question 7? (Q8)

____

____

Appendix B

3 R's Student Survey   August 24, 1994   Code # ____

Please use this scale to answer the following questions:

SA --- Strongly Agree
A --- Agree
N --- Neither agree nor disagree
D --- Disagree
SD --- Strongly Disagree

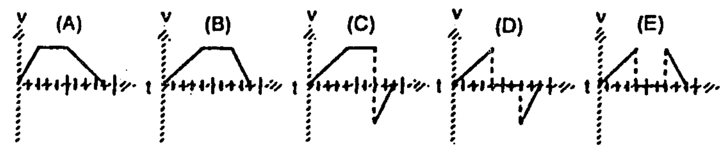
(Circle one choice.)

18.	SA A N D SD	Science is fun.
19.	SA A N D SD	I do not like science and it bothers me to have to study it.
20.	SA A N D SD	During science class, I usually am interested.
21.	SA A N D SD	I would like to learn more about science.
22.	SA A N D SD	If I knew I would never go to science class again, I would feel sad.
23.	SA A N D SD	Science is interesting to me and I enjoy it.
24.	SA A N D SD	Science makes me feel uncomfortable, restless, irritable, and impatient.
25.	SA A N D SD	Science is fascinating and fun.
26.	SA A N D SD	The feeling that I have towards science is a good feeling.
27.	SA A N D SD	When I hear the word science, I have a feeling of dislike.
28.	SA A N D SD	Science is a topic which I enjoy studying.
29.	SA A N D SD	I feel at ease with science and I like it very much.
30.	SA A N D SD	I feel a definite positive reaction to science.
31.	SA A N D SD	Science is boring.

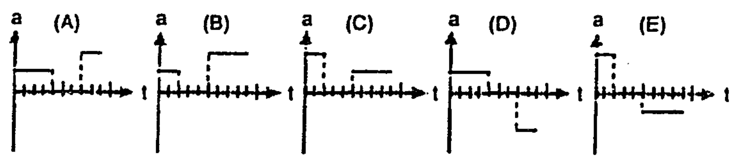
Mechanics Baseline Test

- **Refer to the diagram below when answering the first two questions. This diagram represents a multiflash photograph of an object moving along a horizontal surface. The positions as indicated in the diagram are separated by equal time intervals. The first flash occurred just as the object started to move and the last just as it came to rest.**

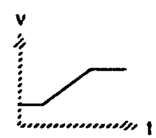
1. Which of the following graphs best represents the objects velocity as a function of time?

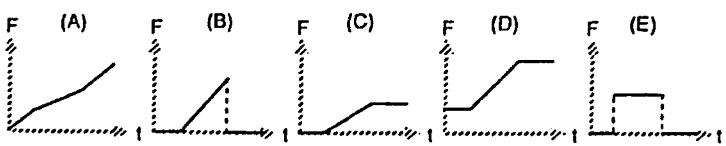


2. Which of the following graphs best represents the object's acceleration as a function of time?



3. The velocity of an object as a function of time is shown in the graph at the right. Which graph below best represents the net force-vs.-time relationship for this object?

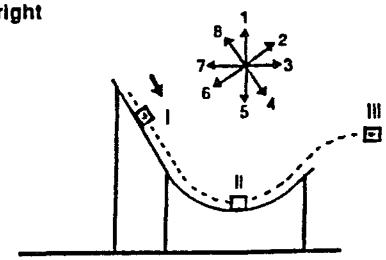




1

- **Refer to the graph on the right when answering the next three questions.**

This diagram depicts a block sliding along a frictionless ramp. The eight numbered arrows in the diagram represent directions to be referred to when answering the questions.



4. The direction of the acceleration of the block, when in position I, is best represented by which of the arrows in the diagram?

   (A) 1 (B) 2 (C) 4 (D) 5
   (E) None of the arrows, the acceleration is zero.

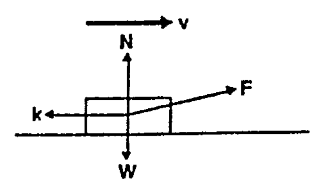
5. The direction of the acceleration of the block when in position II is best represented by which of the arrows in the diagram?

   (A) 1 (B) 3 (C) 5 (D) 7
   (E) None of the arrows, the acceleration is zero.

6. The direction of the acceleration of the block (after leaving the ramp) at position III is best represented by which of the arrows in the diagram?

   (A) 2 (B) 3 (C) 5 (D) 6
   (E) None of the arrows, the acceleration is zero.

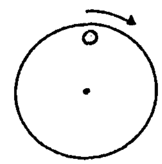
7. A person pulls a block across a rough horizontal surface at a **constant speed** by applying a force F. The arrows in the diagram correctly indicate the directions, but not necessarily the magnitudes of the various forces on the block. Which of the following relations among the force magnitudes W, k, N, and F **must be true?**

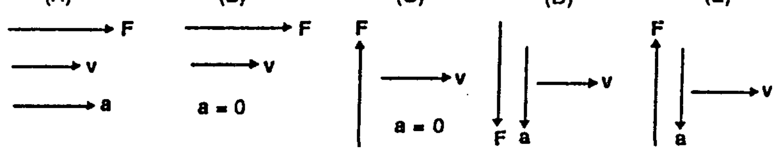


   (A) F = k and N = W (B) F = k and N > W
   (C) F > k and N < W (D) F > k and N = W
   (E) None of the above choices

2

8. A small metal cylinder rests on a circular turntable, rotating at a constant speed as illustrated in the diagram at the right. Which of the following sets of vectors best describes the velocity, acceleration, and net force acting on the cylinder at the point indicated in the diagram?

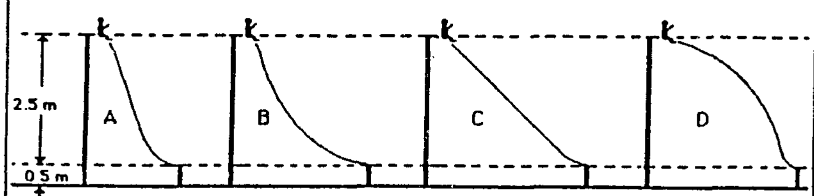




9. Suppose that the metal cylinder in the last problem has a mass of 0.10 kg and that the coefficient of static friction between the surface and the cylinder is 0.12. If the cylinder is 0.20 m from the center of the turntable, what is the maximum speed that the cylinder can move along its circular path without slipping off of the turntable?

(A) $0 < v \leq 0.5$ m/s (B) $0.5 < v \leq 1.0$ m/s
(C) $1.0 < v \leq 1.5$ m/s (D) $1.5 < v \leq 2.0$ m/s
(E) $2.0 < v \leq 2.5$ m/s

10. A young girl wishes to select one of the **frictionless** playground slides illustrated below to give her the greatest possible speed when she reaches the bottom of the slide.

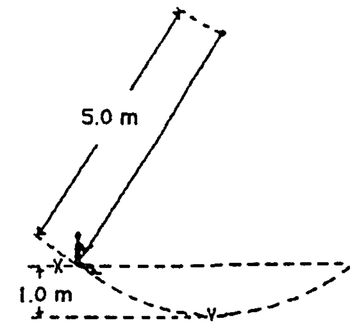


Which of the slides illustrated in the diagram above should she choose?

(A) A (B) B (C) C (D) D
(E) It doesn't matter, her speed would be the same for each.

- **Refer to the diagram below when answering the next two questions.**

X and Z mark the highest and Y the lowest positions of a 50.0 kg boy swinging as illustrated in the diagram to the right.



11. What is the boy's speed at point Y?

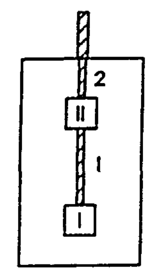
(A) 2.5 m/s (B) 7.5 m/s
(C) 10. m/s (D) 12.5 m/s
(E) None of the above.

12. What is the tension in the rope at point Y?

(A) 250 N (B) 525 N (C) 7×10^2 N (D) 1.1×10^3 N
(E) None of the above.

- **Refer to the diagram below when answering the next two questions.**

Blocks I and II, each with a mass of 1.0 kg are hung from the ceiling of an elevator by ropes 1 and 2.



13. What is the force exerted by rope 1 on block I when the elevator is traveling upward at a constant speed of 2.0 m/s?

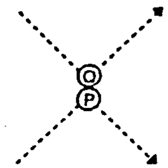
(A) 2 N (B) 10 N (C) 12 N
(D) 20 N (E) 22 N

14. What is the force exerted by rope 1 on block II when the elevator is stationary?

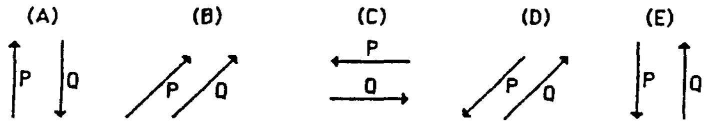
(A) 2 N (B) 10 N (C) 12 N (D) 20 N (E) 22 N

- **Refer to the following diagram when answering the next two questions.**

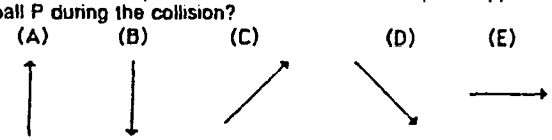
The diagram to the right depicts the paths of two colliding steel balls, P and Q.



15. Which set of arrows best represents the direction of the change in momentum of each ball?



16. Which arrow best represents the direction of the impulse applied to ball Q by ball P during the collision?



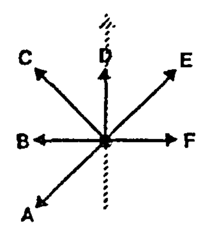
17. A car has a maximum acceleration of 3.0 m/s². What would its maximum acceleration be while towing a second car twice its mass?

(A) 2.5 m/s² (B) 2.0 m/s² (C) 1.5 m/s²
(D) 1.0 m/s² (E) 0.5 m/s²

18. A woman weighing 6.0×10^{2} N is riding an elevator from the 1st to the 6th floor. As the elevator approaches the 6th floor, it decreases its upward speed from 8.0 to 2.0 m/s in 3.0 s. What is the average force exerted by the elevator floor on the woman during this 3.0 s interval?

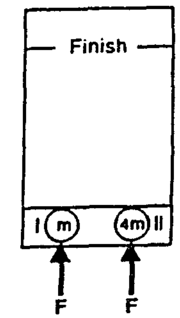
(A) 120 N (B) 480 N (C) 600 N
(D) 720 N (E) 1200 N

19. The diagram at the right depicts a hockey puck moving across a **horizontal, frictionless** surface in the direction of the dashed arrow. A constant force F, shown in the diagram, is acting on the puck. For the puck to experience a net force **in the direction of the dashed arrow,** another force must be acting in which of the directions labeled A, B, C, D, E?



- **Refer to the diagram below when answering the next three questions**

The diagram depicts two pucks on a frictionless table. Puck II is four times as massive as puck I. Starting from rest, the pucks are pushed across the table by two **equal** forces.



20. Which puck will have the greater kinetic energy upon reaching the finish line?

(A) I (B) II
(C) They both have the same amount.
(D) Too little information to answer.

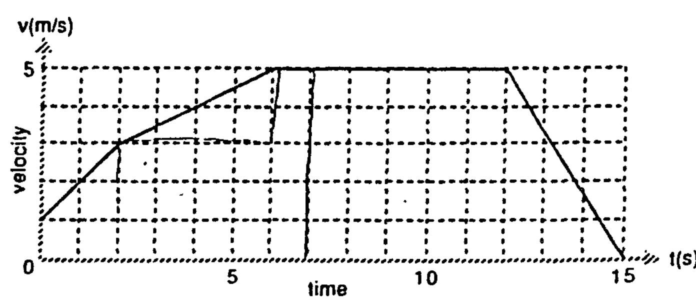
21. Which puck will reach the finish line first?

(A) I (B) II
(C) They will both reach the finish line at the same time.
(D) Too little information to answer.

22. Which puck will have the greater momentum upon reaching the finish line?

(A) I (B) II
(C) They will both have the same momentum.
(D) Too little information to answer.

- **Refer to the following kinematical graph when answering the next three questions.**



The graph represents the motion of an object moving in one dimension.

23. What was the objects average acceleration between t = 0 s and t = 6.0 s?

(A) 3.0 m/s^2 (B) 1.5 m/s^2 (C) 0.83 m/s^2 (D) 0.67 m/s^2
(E) None of the above.

24. How far did the object travel between t = 0 and t = 6.0 s?

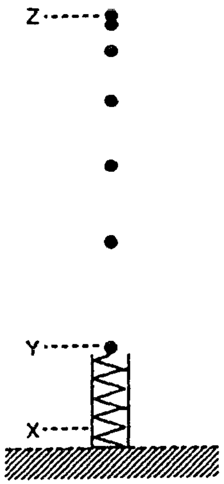
(A) 20. m (B) 8.0 m (C) 6.0 m (D) 1.5 m
(E) None of the above.

25. What was the average speed of the object for the first 6.0 s?

(A) 3.3 m/s (B) 3.0 m/s (C) 1.8 m/s (D) 1.3 m/s
(E) None of the above.

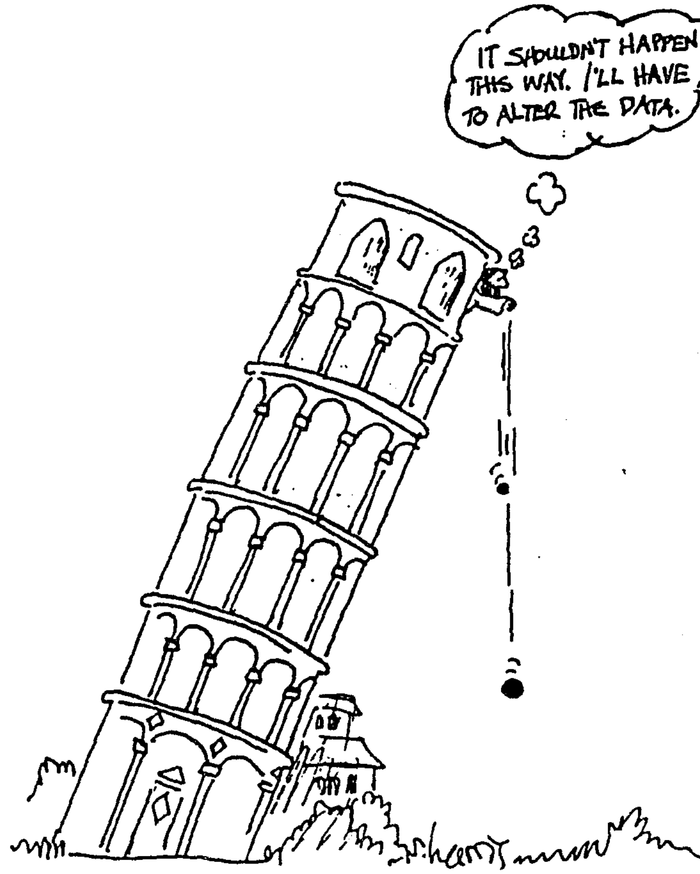
- **Refer to the diagram in the right margin to answer the following question.**

The figure represents a multiflash photograph of a small ball being shot straight up by a spring. The spring, with the ball atop, was initially compressed to the point marked X and released. The ball left the spring at the point marked Y, reaches its highest point at the point marked Z.



26. Assuming that the air resistance was negligible;

(A) The acceleration of the ball was greatest just before it reached point Y (still in contact with the spring).
(B) The acceleration of the ball was decreasing on its way from point Y to point Z.
(C) The acceleration of the ball was zero at point Z.
(D) All of the above responses are correct.
(E) The acceleration of the ball was the same for all points in its trajectory from points Y to Z.



Appendix C

Interview Protocol For Attitude Change

Say to the student: I want to thank you for agreeing to participate in this interview. You understand that your instructor and TA will not be able to identify you in any way. This interview will be transcribed. In other words, the researcher will only see the typed response to the questions I am going to ask you. The original taped interview will be kept by Dr. Hoffman. The researcher will not have access to the tapes.

1. Tell me about your experience in your physics class this semester at UNC-G.

Probes: How does the experience compare with your experience in previous science courses?
What did you like about the course?
Did you enjoy the laboratory experiences?

2. Do you feel like you were doing real science: in other words do you feel like you did things that real scientists do in a lab?

3. What do you think real science is really like?

4. Has this course in any way influenced your decision to enroll in other science courses?

Probes In what way?

If answer is yes what other courses did you take?

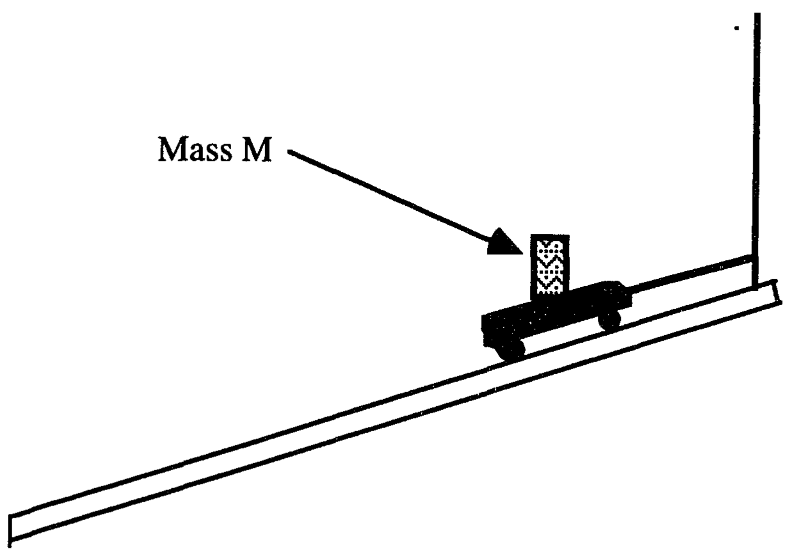
5. Has this course in any way influenced your career choice?

How?

6. In general what role do you feel women should play in the sciences?

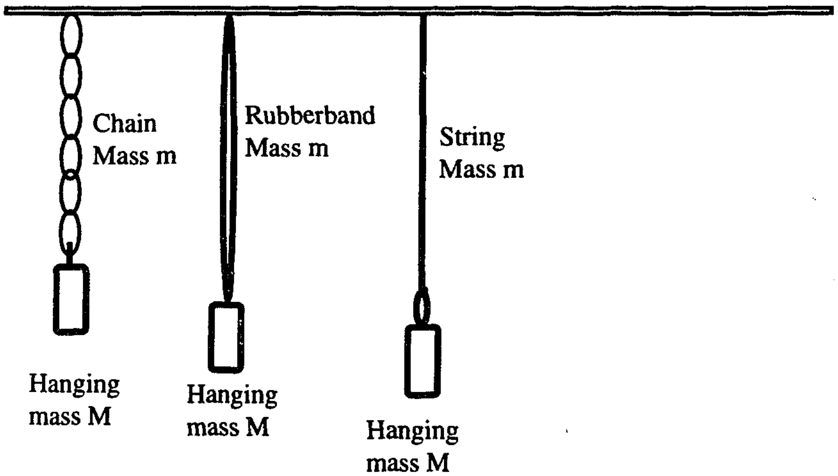
Tasks to Identify Conceptual Change

1. Set up a dynamics cart as follows:



Ask students to identify all forces in the given situation.

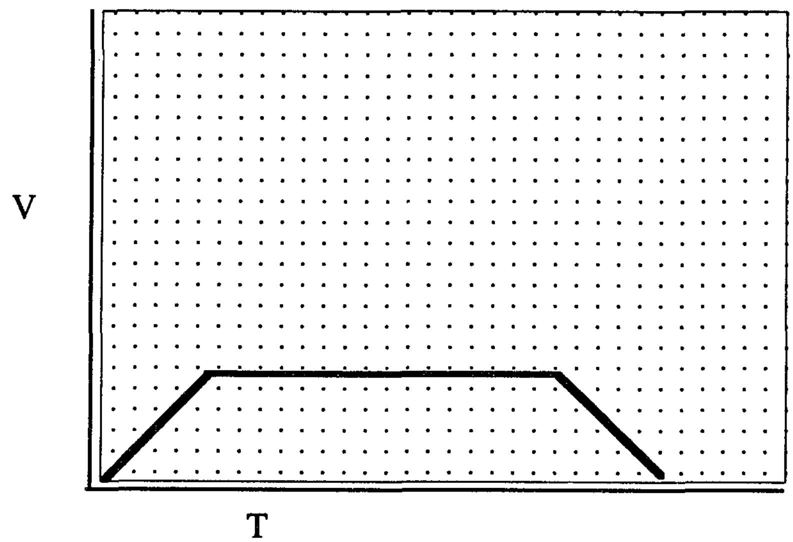
2. Consider the following situation:

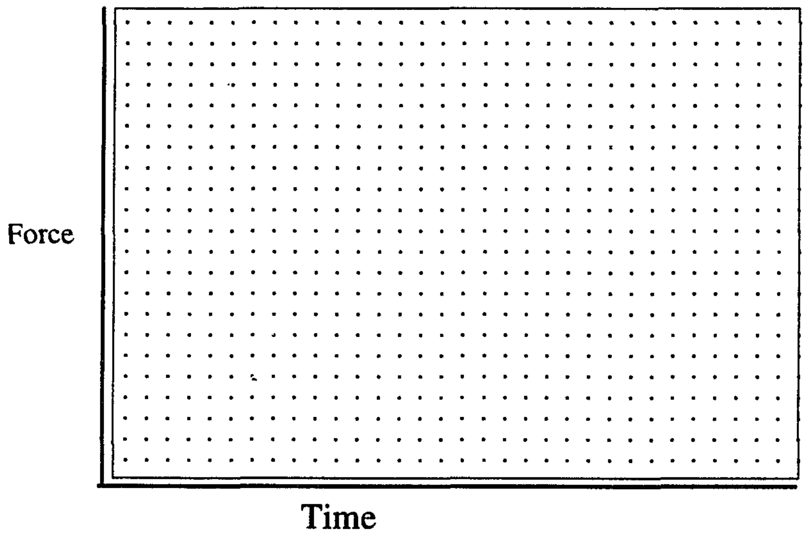


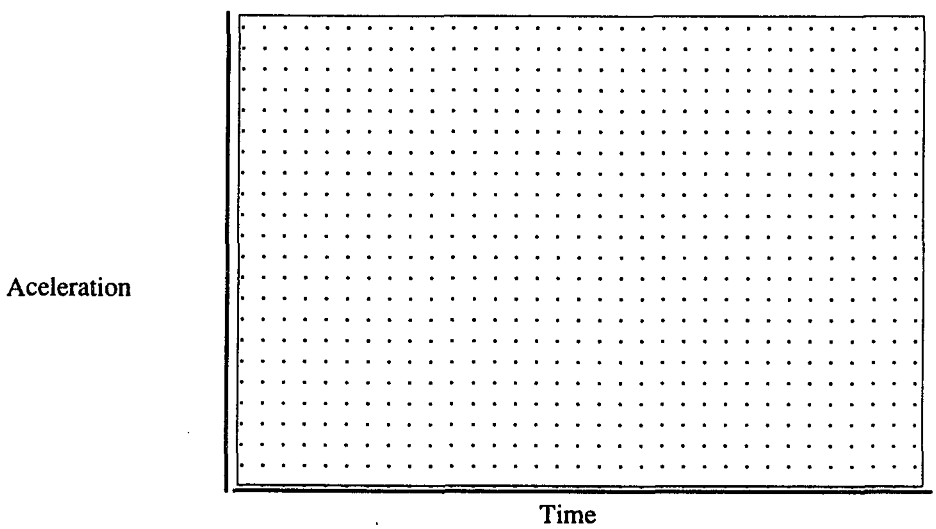
Which has the greatest tension force?

3. The velocity of an object as a function of time is shown in the graph below. Please draw the acceleration vs. time graph that best represents the acceleration of the object over time t.

Please draw the force vs. time graph that best represents the force of the object over time, t.




Force
Time


Aceleration
Time