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ABSTRACT

This paper reports on a study that used Hestenes' Force Concept Inventory (FCI) to describe Newtonian force concepts and misconception belief systems held by preservice teachers in physical science and physics students attending an urban university in Chicago, Illinois. Results indicate that constructivist instruction in force concepts was of higher quality than traditional instruction. Several significant correlations are also reported between FCI scores and parental education level, the number of science and math courses taken in high school or college, gender, science/math anxiety, and perception of difficulty scores in science and math. An annotated bibliography and copies of questionnaires used in the study are included in the appendices. (Contains 35 references.) (WRM)

Running head: FORCE CONCEPT CORRELATIONS

A Force Concept Correlation Study with Instructional Methods, Anxiety, Perceptions of Difficulty and Student Background Variables

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Abstract

This study (1) used Hestenes' Force Concept Inventory (FCI) to describe Newtonian force concept and misconception belief systems held by preservice teachers in physical science and physics students attending an urban university in Chicago, Illinois; (2) found that force concept constructivist instruction was of higher quality (n=48); and (3) determined several significant correlations between the FCI scores and parental educational level, the number of science and math courses taken in high school or college, gender, science/math anxiety and perception of difficulty scores in science and math. Algebra and educated mothers led to the most significant correlations. The FCI, Student Background Survey, Perception of Difficulty and Anxiety questionnaires, and an annotated bibliography on force concept misconceptions are included.

A Force Concept Correlation Study with Instructional Methods, Anxiety, Perceptions of Difficulty and Student Background Variables

There are a number of educators who are concerned about the presence of student misconceptions prior to, during, and even after the process of instructional intervention. This project will examine a narrow part of this educational crisis: the common-sense misconceptions of the scientifically accepted Newtonian concept of force.

Several researchers have shown that students of various educational levels in several countries of the world hold notions that do not agree with officially appropriate views of the concepts that explain force. This body of research includes work at the college level by Arditzogolu and Crawley (1990); Crawley and Arditzogolu (1988); Ginns and Watters (1995); Hake (1998); Hestenes, Wells, and Swackhammer (1992); Pilburn, Baker, and Treagust (1988); Preece (1997); and Trumper (1997). Crawley and Arditzogolu (1988) in particular have shown that misconceptions are "systematic, intelligently conceived, and quite reasonable theories" based on an individual's experience. Although studies by Basili and Sanford (1991), Hestenes et al. (1992), and Lawrenz (1987) show that a change in the number and types of force concept misconceptions can be accomplished, these unacceptable theories continue to exist.

The interested reader may choose to examine the writings of researchers who have investigated the sources, outcomes, and implications of students and teachers who hold several types of force concept misconceptions. Appendix A is an annotated bibliography of current work in this area for various age groups and education levels.

The focus of this empirical research study is three-fold in nature. The first goal is to provide a description of the types of scientifically correct Newtonian force concept or common-sense misconception beliefs held by students in the research sample. The second goal is to compare the quality of force concept instruction (measured pre/post by the Force Concept Inventory, Appendix B, developed by Hestenes et al. (1992)) given to the three classroom samples. The third goal is to determine whether or not there are any significant correlations between the force concept competency levels and variables yet to be discussed.

The multi-correlational part of the study will structured as follows: The independent variable will be the Force Concept Inventory scores for Physical Science 110: Physical Science for Pre-service Elementary and Middle School Teachers and for Physics 211: Introduction to Mechanics for Physics and Engineering Majors. The dependent variables include parental educational level, the number of science and math courses taken in high school or college, gender, science/math anxiety and perception of difficulty scores in science and math.

A number of research studies address these variable relationships. The most relevant empirical education studies at the post-secondary level include works by Bitner (1992 a, b) as well as Hestenes, Wells, and Swackhammer (1992); Hake (1998); Everson, Tobias, and Hartman (1993); and Farmer (1990). A brief examination of other supporting studies will follow.

Bitner (1992 b) wanted to identify any significant relationships between misconceptions in physical science and the following factors: formal reasoning scores, ACT Science Scores, and Process Skills. Her subjects of interest were Teacher Education Program students at a midwestern university of approximate enrollment of 20,000. Bitner chose a causal-comparative study in which frequency and two-way ANOVA ($p<0.01$) were used to analyze the data. The results indicate that a higher percentage of pre-service secondary science methods teachers (85%) were formal reasoners than the pre-service elementary science methods teachers (68%). Secondary teachers were more able to identify and state an hypothesis and demonstrated fewer physical science misconceptions than their elementary counterparts. In addition, the ACT Science scores were higher for the secondary group.

Bitner (1992 a) presented a companion casual-comparative study using the same student population pool as above. Her research indicates that no significant gender-related differences ($p<0.01$) in aptitude, achievement, or attitudes about science and science teaching were found in elementary pre-service teachers ($n=80$).

Hestenes et al. (1992) published an extensive work on the contrast between Newtonian physics and common-sense student-held belief systems based on studies with over 1500 high school students, 500 university students, seven professors, and 19 high school teachers from Arizona, Illinois, and Massachusetts. Results indicated that math background and socioeconomic levels (particularly ethnicity, income level, and gender) were independent of post-test Force Concept Inventory scores. Severe deficiencies in the English language was found to have a negative impact on scores. Strong pedagogy was positively correlated to scores. The study provided substantial evidence to support the claim that the use of "technology by itself" cannot improve the instructional quality. Rather, the supplemental use of technology was found to enhance good pedagogy as long as it did not replace quality instruction.

The Hestenes et al. (1992) research indicated that students lack certain concepts and modes of reasoning needed to be successful in a traditional problem-solving course structure. In the traditional physics or physical science course, students are not being exposed to kinematics using graphing skills to diagram the relationships of motion—speed, distance, and acceleration—and forces. Instructors and textbooks fail to address this issue adequately. Therefore, the researchers were able to positively correlate the quality of instruction in this area with the scores on the Force Concept Inventory.

Hake (1998) compiled an extensive study from a nationally diverse sample (n=6542) that includes test results from the leading instruments on force concepts: the Force Concept Inventory (FCI), the Halloun-Hestenes Mechanics Diagnostic test (MD), and the Mechanics Baseline test (MB). The MD test was developed by Halloun and Hestenes (1985) and is the original instrument that was later adapted into the well-respected FCI. The problem-solving MB instrument developed by Hestenes and Wells (1992) is a companion of the MD test.

To investigate the impact of course instruction, Hake arranged the student data into two sets: traditional (n=2084) and interactive-engagement (n=4458). He defines interactive-engagement (IE) as those teaching methods in which use "heads-on (always) and hands-on (usually) activities" that encourage discussion. Hake defines traditional courses as those that do not employ IE methods and that rely on "passive-student lectures, recipe labs, and algorithmic-problem exams." His research suggests that the use of IE activities is much more effective than traditional instructional methods. In addition, results based on the Mechanics Baseline (n=3259) test show that problem-solving ability is enhanced by IE strategies. Hake's analysis supports Hestenes' work in that Hestenes' "quality of instruction" may very well include interactive-engagement activities.

Everson et al. (1993) wanted to develop empirical support for the claim that rigorous subjects such as mathematics and science produce more anxiety than the humanities. The subjects were first-year college students from a large urban university. The sample (n=196) was ethnically diverse: 41% African American, 31% Hispanic, 18% Asian American, 5% White, and 5% others. The ages ranged from 17 to 38 years old with a mean age of 21. Everson et al. chose to randomly assign treatment groups in a 4 X 3 factorial design. Students in the study group were more anxious about Mathematics and Physical Science courses than with English or Social Studies. Physical Science was the highest. Student perceptions about difficulty was positively correlated with anxiety although the data suggests other factors may be involved. Students who were asked to give precise/accurate answers had no significant difference on the perception of difficulty than students required to give conceptual/less rigorous answers. Gender also did not have a significant effect on the perceptions of difficulty in any subject matter.

Farmer (1990) reported the assessment results of a newly revised program to improve student achievement and preparedness in physical science instruction at a technical college in South Carolina. It was determined that male students scored 12.3% higher on the American Testronic's High School Subject Test (HSST) in physical science than female students. A positive correlation between the number of high school science courses taken and students' scores on the HSST was found, although there was no significant effect noted if students took less than three science courses at the college level. Students in the Associate Degree and College Transfer Programs seemed to obtain higher HSST scores than all other programs. One-fourth of the sample (n=219) scored below the HSST 50th percentile. In addition, Farmer believes that the scores were low because few of the student sample population took high school physics. He noted that the lowest concept area scores consisted of topics that should have been taught in high school physics.

Navarro (1989) conducted a study (n=1,829) which concluded that apparent gender differences on the Math portion of the Scholastic Aptitude Test were really an effect of how many math, computer science and physics courses had been taken. In addition, Santiago and Einarson (1996) found that academic outcomes were not dependent on gender and ethnicity. These two works, developed independently of Farmer's research (1990), echoes his themes.

An interesting minor variable to investigate is a correlation between parental education level with Force Concept Inventory scores. Young and Smith (1997) of the National Center for Educational Statistics issued a report that found, among other things, that student achievement is closely related to the level of education of their parents—mothers in particular. However, these researchers did not single out physical science instruction as an individual variable.

The literature does not always clearly define what topics belong in a course entitled "Physical Science." A scientist doing research in the physical science field studies physical and chemical processes of matter and not the life processes of matter that would be studied by biologists. Literature that refers to physics, chemistry, earth science/geology, and astronomy are equally valid subtopics within physical science. In order to maintain clarity for this project, the subjects in this study are being taught force concepts from Newtonian physics using different instructional techniques.

The study will investigate a number of hypotheses. (1) It is expected that the Physical Science 110 classes will receive a higher quality level of instruction using a guided-inquiry/constructivist approach with hands-on laboratory activities than the Physics 211 verification-style lecture and laboratory exercises. This hypothesis will be considered valid if the Physical Science 110 classes exhibit a larger change in the pre/post-instruction Force Concept Inventory scores. This would indicate that more correct Newtonian force concepts and fewer incorrect force concepts (misconceptions) are presently held by students. (2) It is surmised that student's with college-educated parents or a course history background that includes more than 3 science classes in high school or college will have a positive correlation with the Force Concept Inventory scores. (3) A high anxiety level or a high perception of difficulty in science and math is hypothesized to have a negative correlation with the Force Concept Inventory scores. In addition, (4) gender is not expected to play a significant role.

Method

- **Participants**

The subjects of the study (n= 48) were drawn from an urban university in Chicago, Illinois. As of the Fall 1998, the student population consisted of 92% African Americans, 6% Hispanic, 1% other minority groups, and 1% Caucasian. The campus supports mainly commuter students although a few students now live in a single on-campus dormitory. The typical range of student ages at this university are between 18 and 45. Currently, there is an open enrollment policy. The average number of years required to finish a bachelor's degree is six years. This average is attributed to the large number of students who arrive under-prepared for college courses from the local city school system.

The three student groups in this multi-correlational study were chosen ex post facto. Two of the groups were technically the same course although the time of class (evening versus afternoon) seemed to have generated slightly different student compositions. This course, Physical Science 110, has been developed for pre-service elementary and middle school teachers. The third group of students were enrolled from Physics 211 entitled: Introduction to Mechanics for Science Majors. Occasionally students other than those for which these courses were intended have enrolled in these courses. These students were kept in the study.

The pooled data included 48 subjects (12 male and 36 female). The group ethnicity was 79.2% African American, 0.00% Caucasian, 14.6% Hispanic, 1.4% Native American, and 2.8% Other. The subjects' range in ages were 18 to 45.

The Physical Science 110 evening class, PS 110-61, had 20 subjects (3 male and 17 female) of which 70% were African American, 25% were Hispanic, and 5% were Native American. The afternoon class, PS 110-01, has 16 subjects (2 male and 14 female) of which 81.25% were African American, 6.25% were Hispanic, and 12.5% were other. The subjects' range in ages for the evening and afternoon sections were 20 to 38 and 18 to 45, respectively.

The Physics 211 course, Phy 211-01, was designed for physics and engineering majors although other science and math majors participate in the instruction. This class of 12 students (7 male and 5 female) consisted of 91.67% African American and 8.33% Hispanic. The subjects ages in this course were 18 to 25 and one 31-year old.

- **Materials**

The most important instrument that was used in this study is the Force Concept Inventory developed by Hestenes et al.(1992). It was designed to elicit information about the belief systems of force concepts held by an individual or group—not intelligence levels. This 29 question, multiple-forced-choice instrument required students to select either a scientifically accepted Newtonian belief answer or a common-sense misconception response. It was tested with over 2000 subjects. It is considered in the literature as valid and reliable although no coefficients have been published. A copy of the Force Concept Inventory can be found in Appendix B. Appendix C contains a table that categorically compares Newtonian force concepts and their corresponding common-sense misconceptions.

The force concept inventory results can be used to look at the quality of an individual's force concept belief system. Using the baseline data provided by Hestenes et al. (1992), five distinct benchmark levels were developed for this project: expert, practitioner, high school/first-year physics course student, a junior high general science student, and a novice. An expert in Newtonian physics would need to score 29/29 (100%). False-positive and false-negative responses bring the practitioner threshold to 23/29 (80%). A physics course student, either in high school or first-year college is shown to realistically score 17/29 (60%). The general science student would most likely reach the 12/29 (40%) benchmark. Novices have been shown to use common-sense beliefs through experiences to attain a 6/29 (20%) score.

Three survey/questionnaire forms were developed for this investigation. A Student Background survey was modified from an example published by Farmer (1990). A Likert-scale type survey to examine the student perceptions of difficulty in science, math, and humanities was modeled after and adapted from Everson (1993). A scalar questionnaire to explore the anxiety levels of students taking science and math courses was also adapted from the Worry-Emotionality Questionnaire in Everson's work (1993). Non-participant science and non-science major students were asked to check their comprehension of the instruments prior to distribution. In addition, participant-students were questioned after distribution to clarify any possible misunderstandings, especially the (English-as-second-language) bilingual Hispanic population. These instruments can be located in Appendices D to F, respectively.

- Procedure

Students were given the Force Concept Inventory as a pre-test and the three survey/questionnaires. This occurred approximately 5 or 6 weeks into the semester-long courses. The students were then given their respective Newtonian force concept instruction. The Physical Science 110 course used guided-inquiry and constructivist approaches to instruction with hands-on laboratory activities. The two instructors of this course worked closely with each other and frequently visited each others classes to maintain the common goals and quality of instruction of the course. (The evening class met once a week for four hours and the afternoon class met the equivalent number of hours twice a week.)

The Physics 211 course followed a traditional lecture approach that included verification-style lectures and laboratory experiments with problem solving sessions. All three classes received the equivalent of one week of instruction and one week of occasional review prior to a mid-term examination for the course. The week after the mid-term examinations, the students were given the Force Concept Inventory as a post-test.

Collected data was then examined. Potential problems were identified and addressed by interviewing the individual students who submitted the surveys. Decisions had to be made about students who gave more than one variable the same rank. (The word 'rank' was a particular problem for the bilingual students.) In those cases in which there was given, for example: 2, 3, 4, 5, 5; The recorded rank became 1, 2, 3, 5, 5. Similarly the set: 1, 1, 1, 2, 2 was recorded as: 1, 1, 1, 4, 4. This kind of problem happened only occasionally.

Upon re-examination of the literature to develop a plan for calculating variables such as the Anxiety scores and the Perception of Difficulty scores in Science or Math, it was discovered that there were no existing explanations. The Perception of Difficulty and Anxiety scales were developed using the following equation: $[(n \times v) - n = \text{score}]$ where n equals the total number of questions and v equals the Likert scale maximum/minimum value. For example, the Perception of Difficulty scores have five questions (n=5) which has a maximum value of 5 and a minimum value of 1 for each question. Therefore, the maximum score is 20 and the minimum score is zero. Likewise, the range of Anxiety scores are between zero and 40. High scores indicate high perception of difficulty or anxiety.

The total scores were calculated as follows. The Perception of Difficulty in science was tabulated using a positive Likert Scale (1 to 5) for questions 3 and 7, a reversed scale for question 5, the ranking of Physical Science in question 9, and the ranking of physics in question 10. Questions used for math include 4, 6, 8, 9 (math), and 10 (scientific math). The science/math Anxiety scores used positive Likert-scale values for questions 1-9 and used a reverse scale on question 10.

There was a concern that the Force Concept Inventory Pre/Post scores might not accurately reflect the concepts taught. Indeed, only kinematics and

Newton's first three Laws were explicitly taught in the Physical Science 110 classes. In hindsight, the Physics 211 instructor implicitly decided that his students were adequately prepared and quickly moved into more difficult areas of force concepts beyond the first three laws. As a precaution for later data analysis, an adjusted Force Concept Inventory score was calculated using the students results for only the Kinematics and first three Laws scores. The data will show that this precaution, although useful, was not entirely necessary. In addition, the change of Force Concept Inventory scores was calculated as well.

Analysis and Results

The resulting analyses will be presented in a logical order that hopefully will lead to a clear picture of the project. Each of the four separate hypotheses will be addressed by examining the data. Lastly, additional relationships that were discovered will be discussed.

There are several appendices provided that contain summary data of the population sample. Appendix G presents the means of the pre-/post-Force Concept Inventory scores and the scores for each force correct concept or misconception category. Pooled data are summarized in Appendices H, I and J for the Perception of Difficulty in Science and Math, Anxiety in Science, and Anxiety in Math; respectively.

There is clear evidence in Appendix G and in the ANOVA analysis in Appendix K that the Physical Science 110 classes did receive a higher quality of instruction than the Physics 211 course (Hypothesis 1). There is proof that a greater change in the understanding of force concepts did occur. However, it is important to note that the classes did not start at the same level. The average pre-test level of force concept beliefs in the Physical Science 110 classes is below the novice threshold at 5.36/29 (18.5%) and 4.25/29 (14.7%). The Physics 211 students are between the novice stage and the general science student benchmarks at 8.45/29 (29.1%). The students in this population are below the national standards in this area.

Appendix G also shows that the Physics 211 class was better prepared for the force instruction. Yet, there was a smaller improvement in correct force concepts displayed by those students. The quality of instruction is thought to be attributed to teaching style. Further study to include a constructivist approach for the Physics 211 course is warranted.

Appendix L contains the descriptive statistics of the student's course background, the parental education level and the Force Concept Inventory scores. Pearson correlations for these variables are found in Appendix M. The number of high school math courses, particularly algebra, was found to have a significant positive correlation ($p<0.05$) with the pre-test Force Concept Inventory Scores (both regular and adjusted scores). Appendix M also indicates that there were several slightly positive although not significant correlations between the number of high school/post-high school science courses or post-high school math courses taken and the post-instruction Force Concept Inventory Scores: post-high school science > post-high school math, high school math(algebra) > high school science, post-high school science > high school science, and post-high school math < high school math.

It appears that this study supports that general literature consensus that high school algebra (and to a lesser degree math) is the first gateway for success and post-high school science courses are possibly the second (Hypothesis 2). Quality instruction cannot totally compensate for the lack of preparedness, however the constructivist teaching style has shown a stronger impact ($p = 0.08$) on post-instruction Force Concept Inventory scores than the verification teaching style, if not yet significant at $p<0.05$ (Hypothesis 1).

Positive, yet not significant, Pearson correlations exist between the education level of parents and the Force Concept Inventory scores. (See Appendix M.) Although not significant, a mother's educational level has double the impact on the pre-test scores. This early influence may partially explain why this effect nearly disappears for both parents on the post-test. There are most likely additional confounding variables. (Hypothesis 2).

Anxiety and Perception of Difficulty scores (Appendix N) produced unexpected results (Appendix O). The pre-test Force Concept Inventory (FCI) scores were positively and significantly correlated ($p < 0.05$) to the Anxiety of Science scores. Although Anxiety of Math is not significant there is a positive effect shown. (The value is just slightly smaller.) The science and math Anxiety scores have slightly positive non-significant correlations to the post-FCI scores. These positive correlations between high FCI scores and high Anxiety scores is somewhat surprising, but may indicate a positive use of anxiety (Hypothesis 3).

The Perception of Difficulty in math is slightly more negative than science when correlated to the pre-test FCI scores. Interestingly, there was a stronger negative post-correlation of Perception of Difficulty scores in science with the FCI scores than in the Perception of Difficulty scores in Math to the post-FCI scores. The students appear to show an inverse relationship between Perception of Difficulty and the Force Concept Inventory scores. In other words, a high FCI score may be a result of a low Perception of Difficulty and vice versa (Hypothesis 3).

The role of gender was expected to have no effect on the Force Concept Inventory scores. The pre-test Chi-Square values in Appendix P was verified to be significant to the p=0.0025 level. The post-test values are not significant. However, considering that there were so few males in this study, more data needs collected in the future to validate this result.

Additional conclusions were drawn from this study. (1) A mother's educational level was positively and significantly correlated to the number of post-high school science and math courses taken (both $p<0.01$). Although not significant, there was also a positive impact on the number of high school science and math classes taken. (2) A father's educational level was significantly and positively correlated to the number of post-high school science and math courses taken (both $p<0.05$). His educational level had strong although not significant effects on the number of high-school science and math courses taken. (3) Educated women and educated men become educated parents ($p<0.01$). (4) A father's educational level leads to more anxiety in math ($p<0.06$) yet his offspring seem to perceive math as less difficult. (5) A mother's educational level may influence the offspring to perceive science and math as less difficult and has a strong yet not significant influence over math anxiety. (6) Science anxiety positively correlates to math anxiety ($p<0.01$). (7) The Perception of Difficulty in Science has a small negative correlation to the Perception of Difficulty in Math. (8) The Perception of Difficulty in Science has a significant negative correlation with Anxiety in Science ($p<0.05$). (9) The Perception of Difficulty in Math was negatively correlated to the Anxiety in Math ($p<0.01$).

Discussion

This research project should be considered a preliminary investigation into these variables. Further examination is needed. In particular, the culture in which these minority students have been raised has an impact on their anxiety and perception of difficulty levels as well as their achievement and level of comprehension of the concepts of Force. Is this sample truly unique in preparedness levels for force concept instruction at the college level in comparison to other schools around the country?

Evidence of gateways for development of correct Newtonian force concepts needs additional study. Algebra has already been identified as the most likely first gateway. But to what extent does the skills needed for chemistry and biology classes or advanced mathematics modify the belief systems from Aristotelian physics to Newtonian physics?

The extent to which the type of instructional method chosen to teach the force concepts has an impact on the force concept belief systems needs explored. In addition, the preservice teachers in this study have been affected by the constructivist method of teaching. Will that modeled teaching style be transferred and have an effect on future students?

Additional investigations might include a comparison between the change of Force Concept Inventory scores for students who scored at the extremes. Will a high pre-test score move into an even higher post-test score? How much of a change is likely to occur for a student with a low pre-test score? Is there an impact from the collaborative process used in the constructivist teaching approach? And lastly, what are the relationships between all of these questions and the variables of Anxiety, Perception of Difficulty, student background, course history, and parental education level?

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Appendices

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Appendix A: Annotated Bibliography on Force Concept Misconceptions

Please note: This appendix includes references at all educational levels.

Arditzoglou, S. Y., & Crawley, F. E. (1990, Apr). *A descriptive study of alternative life and physical science conceptions of preservice elementary teachers.* (ERIC Document Reproduction Service No. ED 324 225) • Designed the Life Science Misconceptions Test and the Physical Science Misconceptions Test. Preservice elementary science teachers were found to hold a total of 36 life science and 50 physical science misconceptions.

Bitner, B. L. (1992 Mar). *Preservice elementary and secondary science methods teachers: comparison of formal reasoning, ACT science, process skills, and physical science misconception scores.* Paper presented at the annual meeting of the National Association for the Research in Science Teaching, Boston, MA. (ERIC Document Reproduction Service No. ED 344 781) • Determined that pre-service secondary teachers demonstrated fewer physical science misconceptions, had more formal reasoning skills, and earned higher ACT science scores than their elementary counterparts.

Boeha, B. B. (1990, Sept). *Aristotle, alive and well in Papua New Guinea science classrooms.* Physics Education, 25 (5), 280-283. • Results indicate Aristolean-like beliefs persist in student's force conceps rather than scientifically accepted Newtonian physics.

Brown, D. E. (1989, Nov). *Students' concepts of force: the importance of understanding Newton's third law.* Physics Education, 24 (5), 353-358. • High school students show misconceptions of Newton's third law.

Brown, W. J. (1992). *Physical science in general education curriculum reform.* (ERIC Document Reproduction Service No. ED 250 171) • Argued the need to develop guided-inquiry curriculum to encourage the students to use decision-making/critical thinking strategies to solve a series of open-ended problems.

Crawley, F. E., & Arditzoglou, S. Y. (1990, Apr). *Life and physical science misconceptions of preservice elementary teachers.* (ERIC Document Reproduction Service No. ED 302 416) • Reported that misconceptions are systematic, intelligently conceived, reasonable theories based on experience, although not always scientifically accepted. Elementary teachers with misconceptions are found to have difficulty transfering scientifically acceptable concepts to their students.

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Gair, J., & Stancliffe, D. (1988). *Talking about toys: An investigation of children's ideas about force and energy.* Research in Science & Technological Education, 6 (2), 167-180. • Eleven-year old children's concepts of force and energy are explored and presented in three frameworks of thought of which only one is scientifically accepted. Gender differences in framework type are reported.

Gamble, R. (1989, Mar). *Force.* Physics Education, 24 (2), 79-82. • Reports misconceptions on the meaning of force, force and motion in one- and two-dimensions, and Newton's second law.

Ginns, I. S., & Watters, J. J. (1995, Feb). *An analysis of scientific understandings of preservice elementary teacher education.* Journal of Research in Science Teaching, 32 (2), 205-222. • Found that pre-service elementary teachers hold misconceptions about scientifically-accepted concepts.

Halloun, I., & Hestenes, D. (1985). *The initial knowledge state of college physics students.* American Journal of Physics, 53, 1043-1055. • Contains the original instrument, the Mechanics Diagnostic Test, which was later modified into the well-respected Force Concept Inventory.

Hestenes, D., Wells, M., & Swackhammer, G. (1992, Mar). *Force concept inventory*. The Physics Teacher, 30 (3), 141-158. • Studied the contrast between Newtonian physics and common-sense Aristotlean belief systems from an extensive and nationally diverse pool of high-school and college students. Results also indicated that strong pedagogy was positively correlated to scores, language deficiencies had a negative impact, and that "technology by itself" does not replace quality instruction. Math background and socioeconomic levels were independent of the scores. The Force Concept Inventory is included in this publication.

Hestenes, D., & Wells, M. (1992, Mar). *A mechanics baseline test*. The Physics Teacher, 30 (3), 159-166. • Reported that students at the high-school and college levels lack certain concepts and modes of reasoning needed to be successful in a problem-solving course structure. Includes the companion instrument to the Mechanic Diagnostic test or its' revised successor, the Force Concept Inventory.

Lawrenz, F. (1987). *Evaluation of a teacher inservice training program in physical science*. Science Education, 71 (2), 251-258. • Reported that a change in the number and types of force concept misconceptions can be accomplished although some unacceptable theories continue to exist.

Liang, L. L. (1997). *Resistance to the implementation of a new constructivist science curriculum for prospective elementary teachers*.. A paper presented at the annual meeting of the American Educational Research Association. (ERIC Document Reproduction Service No. ED 406 209) • Preservice elementary science teachers resisted new constructivist science curriculum. Transfer success was related to the number of positive experiences in conceptual change concept teaching.

Koval, D. B., & Staver, J. R. (1985, Mar). *What textbooks don't teach*. ScienceTeacher, 52 (3), 49-52. • High school technology-training textbooks were found to be inadequate preparation for success in college physical science courses.

Palmer, D. H., & Flanagan, R. B. (1997, Jun). *Readiness to change the conception that "motion-implies-force": a comparison of 12-year-old and 16-year-old students.* Science Education, 81 (3), 317-331. • Older students were found to resist changing alternate misconceptions even though no evidence was found to indicate that older students may be less capable to do so.

Piburn, M. D., Baker, M. D., & Treagust, D. F. (1988, Apr). *Misconceptions about gravity held by college students.* A paper presented at the 61st annual meeting of the National Association for Research in Science Teaching. (ERIC Document Reproduction Service No. ED 292 616) • Reported that although most physical science college students had reasonable conceptions about gravity, misconceptions were prevalent.

Preece, P. F. W. (1997, May). *Force and motion: Pre-service and practising secondary science teachers' language and understanding.* Research in Science & Technological Education, 15 (1), 123-128. • Found that unacceptable views of force and motion concepts are present and that it may lead to the lack of clarity in science instruction.

Salyachivin, S. et al. (1985, Jun). *Students' conceptions on force.* Journal of Science & Mathematics Education in Southeast Asia, 8 (1), 28-31.• Researchers indicate that results of force conceptual frameworks are similar to reported results in western countries.

Summers, M., & Kruger, C. (1993, Sept). *Long term impact of a new approach to teacher education for primary science.* A paper presented at the Annual Meeting of the British Educational Research Association. (ERIC Document Reproduction Service No. ED 362 504) • Reported primary school teachers made significant progress towards the reduction of force and energy misconceptions with proper inservice instruction. Evidence showed that most of the instruction was retained after 6 and 12 months.

Terry, C. et al. (1985). *Children's conceptual understanding of forces and equilibrium.* Physics Education, 20 (4), 162-165. • Children with three to five years of physics instruction were tested about their conceptions of forces and equilibrium. The investigators also explored the issue of maturity in connection to their conceptual framework.

Thijs, G. D. (1992, Apr). *Evaluation of an introductory course on "force" considering students' preconceptions.* Science Education, 76 (2), 155-174. • Constructivist approach instruction effectively changed Dutch secondary school students misconceptions about force in rest and frictional situations.

Trumper, R. (1997, Summer). *The need for change in elementary school teacher training: The case of the energy concept as an example.* Educational Research, 39 (2), 157-174. • Reported that many preservice elementary school teachers hold non-scientifically accepted views on energy and force concepts.

Trumper, R., & Gorsky, P. (1996, Jul). *A cross-college age study about physics students' conceptions of force in pre-service training for high school teachers.* Physics Education, 31 (4), 227-236.• Reported that preservice high school teachers hold serious non-scientifically accepted views on force concepts.

Watts, D. M., & Gilbert, J. K. (1983). *Enigmas in school science: Students' conceptions for scientifically associated words.* Research in Science & Technological Education, 1 (2), 161-171.• Students were found to exhibit non-scientifically accepted views of force and energy. Science instruction and instructional strategy implications are discussed.

Yager, R. E., & Bonnstetter, R. J. (1984). *Student perceptions of science teachers, classes and course content.* School Science and Mathematics, 84 (5), 406-414 in Blosser, P. E., Ed., & Helgeson, S. L., Ed., (1986) Investigations in Science Education, 12 (4). • Elementary teachers admit to not knowing answers to student's questions.

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Force Concept Inventory

1 Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two story building at the same instant of time. The time it takes the balls to reach the ground below will be:

(A) about half as long for the heavier ball.
(B) about half as long for the lighter ball.
(C) about the same time for both balls.
(D) considerably less for the heavier ball, but not necessarily half as long.
(E) considerably less for the lighter ball, but not necessarily half as long.

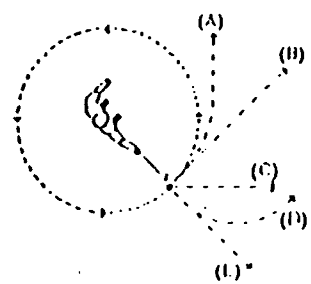
2 Imagine a head on collision between a large truck and a small compact car. During the collision,

(A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
(B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
(D) the truck exerts a force on the car but the car doesn't exert a force on the truck.
(E) the truck exerts the same amount of force on the car as the car exerts on the truck.

3 Two steel balls, one of which weighs twice as much as the other, roll off of a horizontal table with the same speeds. In this situation:

(A) both balls impact the floor at approximately the same horizontal distance from the base of the table.
(B) the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
(C) the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
(D) the heavier ball hits considerably closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
(E) the lighter ball hits considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

4 A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram to the right. At the point indicated in the diagram, the string suddenly breaks at the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.

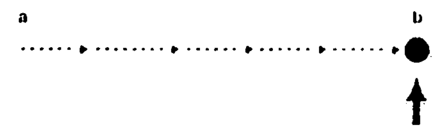


1

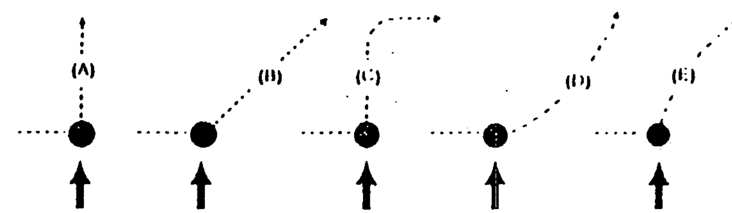
5 A boy throws a steel ball straight up. Disregarding any effects of air resistance, the force(s) acting on the ball until it returns to the ground is (are)

(A) its weight vertically downward along with a steadily decreasing upward force
(B) a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
(C) a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity
(D) a constant downward force of gravity only
(E) none of the above, the ball falls back down to the earth simply because that is its natural action

Use the statement and diagram below to answer the next four questions: The diagram depicts a hockey puck sliding, with a constant velocity, from point "a" to point "b" along a frictionless horizontal surface. When the puck reaches point "b", it receives an instantaneous horizontal "kick" in the direction of the heavy print arrow.



6 Along which of the paths below will the hockey puck move after receiving the "kick"?



7 The speed of the puck just after it receives the "kick"?

(A) Equal to the speed "v_0" it had before it received the "kick"
(B) Equal to the speed "v" it acquires from the "kick", and independent of the speed "v_0"
(C) Equal to the arithmetic sum of speeds "v_0" and "v".
(D) Smaller than either of speeds "v_0" or "v".
(E) Greater than either of speeds "v_0" or "v", but smaller than the arithmetic sum of these two speeds.

2

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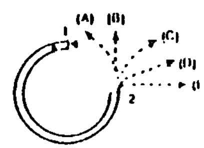
8. Along the **frictionless** path you have chosen, how does the speed of the puck vary after receiving the "kick"?

(A) No change.
(B) Continuously increasing
(C) Continuously decreasing.
(D) Increasing for a while, and decreasing thereafter.
(E) Constant for a while, and decreasing thereafter.

9. The main forces acting, **after** the "kick", on the puck along the path you have chosen are:

(A) the downward force due to gravity and the effect of air pressure.
(B) the downward force of gravity and the horizontal force of momentum **in the direction of motion.**
(C) the downward force of gravity, the upward force exerted by the table, and a horizontal force acting on the puck **in the direction of motion.**
(D) the downward force of gravity and an upward force exerted on the puck by the table.
(E) gravity does not exert a force on the puck, it falls because of the intrinsic tendency of the object to fall to its natural place.

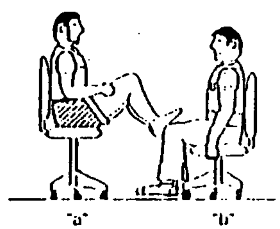
10. The accompanying diagram depicts a semicircular channel that has been securely attached, in a **horizontal plane**, to a table top. A ball enters the channel at "1" and exits at "2". Which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top.



• Two students, student "a" who has a mass of 95 kg and student "b" who has a mass of 77 kg sit in identical office chairs facing each other. Student "a" places his bare feet on student "b's" knees, as shown below. Student "a" then suddenly pushes outward with has feet, causing both chairs to move.

11. In this situation,

(A) neither student exerts a force on the other.
(B) student "a" exerts a force on "b", but "b" doesn't exert any force on "a".
(C) each student exerts a force on the other but "b" exerts the larger force.
(D) each student exerts a force on the other but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.



3

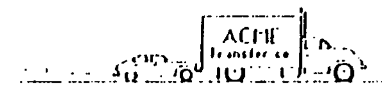
12. A book is at rest on a table top. Which of the following force(s) is(are) acting on the book?

1. A downward force due to gravity.
2. The upward force by the table.
3. A net downward force due to air pressure
4. A net upward force due to air pressure

(A) 1 only
(B) 1 and 2
(C) 1, 2, and 3
(D) 1, 2, and 4
(E) none of these, since the book is at rest there are no forces acting on it

• Refer to the following statement and diagram while answering the next two questions.

A large truck breaks down out on the road and receives a push back into town by a small compact car.



13. While the car, still pushing the truck, is **speeding up** to get up to cruising speed,

(A) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
(B) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
(C) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the car.
(D) the car's engine is running so it applies a force as it pushes against the truck but the trucks engine is not running so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car.

14. After the person in the car, while pushing the truck, reaches the cruising speed at which he/she wishes to continue to travel at a constant speed,

(A) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
(B) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
(C) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the car.
(D) the car's engine is running so it applies a force as it pushes against the truck but the trucks engine is not running so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car

4

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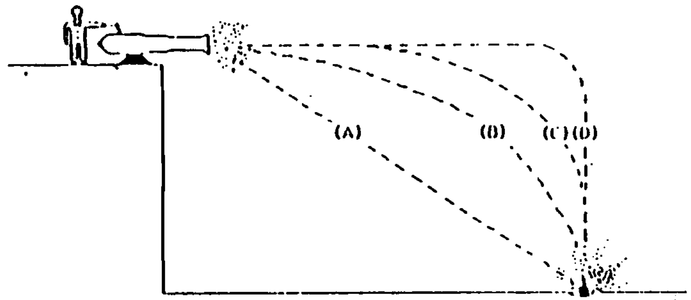
15. When a rubber ball dropped from rest bounces off the floor, its direction of motion is reversed because:

(A) energy of the ball is conserved
(B) momentum of the ball is conserved.
(C) the floor exerts a force on the ball that stops its fall and then drives it upward
(D) the floor is in the way and the ball has to keep moving
(E) none of the above.

16. Which of the paths in the diagram to the right best represents the path of the cannon ball?



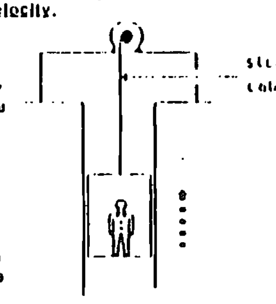
17. A stone falling from the roof of a single story building to the surface of the earth:

(A) reaches its maximum speed quite soon after release and then falls at a constant speed thereafter.
(B) speeds up as it falls, primarily because the closer the stone gets to the earth, the stronger the gravitational attraction.
(C) speeds up because of the constant gravitational force acting on it.
(D) falls because of the intrinsic tendency of all objects to fall toward the earth.
(E) falls because of a combination of the force of gravity and the air pressure pushing it downward.

• When responding to the following question, assume that any frictional forces due to air resistance are so small that they can be ignored.

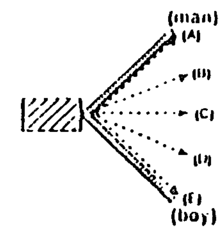
18. An elevator, as illustrated, is being lifted up an elevator shaft by a steel cable. When the elevator is moving up the shaft at a constant velocity.

(A) the upward force on the elevator by the cable is greater than the downward force of gravity.
(B) the amount of upward force on the elevator by the cables equal to that of the downward force of gravity
(C) the upward force on the elevator by the cable is less than the down ward force of gravity.
(D) it goes up because the cable is being shortened, not because of the force being exerted on the elevator by the cable.
(E) the upward force on the elevator by the cable is greater than the downward force due to the combined effects of air pressure and the force of gravity.

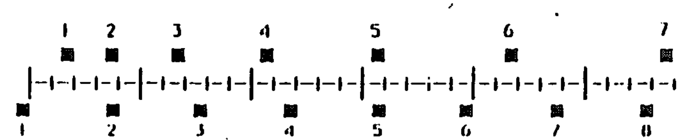


ascending at constant speed

19. Two people, a large man and a boy, are pulling as hard as they can on two ropes attached to a crate as illustrated in the diagram to the right. Which of the indicated paths (A-E) would most likely correspond to the path of the crate as they pull it along?



• The positions of two blocks at successive 0.20 second time intervals are represented by the numbered squares in the diagram below. The blocks are moving toward the right.

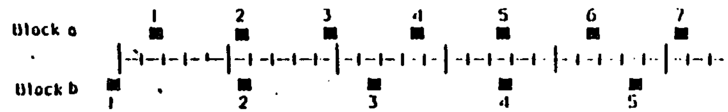


(continued on the next page)

20 Do the blocks ever have the same speed?

(A) No.
(B) Yes, at instant 2.
(C) Yes, at instant 5.
(D) Yes, at instant 2 and 5.
(E) Yes, at some time during interval 3 to 4.

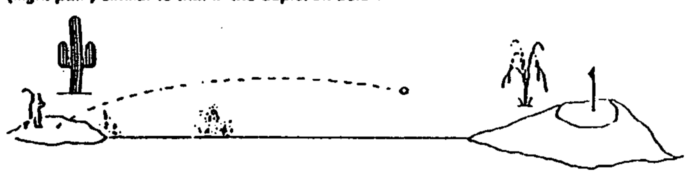
• The positions of two blocks at successive equal time intervals are represented by numbered squares in the diagram below. The blocks are moving toward the right.



21. The acceleration of the blocks are related as follows:

(A) acceleration of "a" > acceleration of "b"
(B) acceleration of "a" = acceleration "b" > 0
(C) acceleration of "b" > acceleration "a"
(D) acceleration of "a" = acceleration of "b" = 0
(E) not enough information to answer.

22. A golf ball driven down a fairway is observed to travel through the air with a trajectory (flight path) similar to that in the depiction below



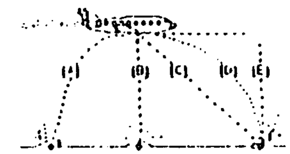
Which following force(s) is(are) acting on the golf ball during its entire flight?

1. the force of gravity
2. the force of the "hit"
3. the force of air resistance

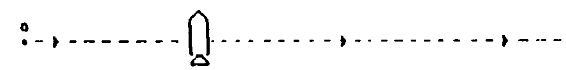
(A) 1 only
(B) 1 and 2
(C) 1, 2, and 3
(D) 1 and 3
(E) 2 and 3

7

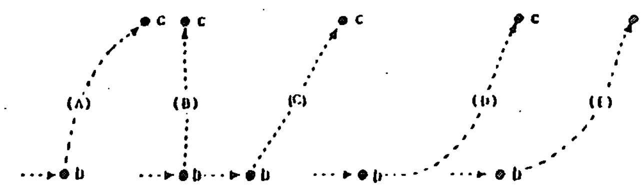
23 A bowling ball accidently falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As soon from the ground, which path would the bowling ball most closely follow after leaving the airplane?



• When answering the next four questions, refer to the following statement and diagram.
• A rocket, drifting sideways in outer space from position "a" to position "b", is subject to no outside forces. At "b", the rocket's engine starts to produce a constant thrust at right angles to line "ab". The engine turns off again as the rocket reaches some point "c".



24. Which path below best represents the path of the rocket between "b" and "c"?



25. As the rocket moves from "b" to "c", its speed is

(A) constant.
(B) continuously increasing.
(C) continuously decreasing.
(D) increasing for a while and constant thereafter
(E) constant for a while and decreasing thereafter.

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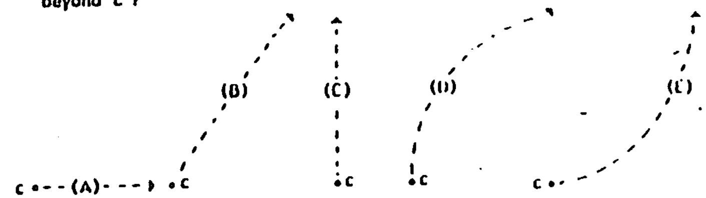
26. At "c" the rocket's engine is turned off. Which of the paths below will the rocket follow beyond "c"?



27. Beyond "c", the speed of the rocket is;

(A) constant.
(B) continuously increasing.
(C) continuously decreasing.
(D) increasing for a while and constant thereafter.
(E) constant for a while and decreasing thereafter.

28. A large box is being pushed across the floor at a constant speed of 4.0 m/s. What can you conclude about the forces acting on the box

(A) If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.
(B) The amount of force applied to move the box at a constant speed must be more than its weight.
(C) The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional forces that resist its motion.
(D) The amount of force applied to move the box at a constant speed must be more than the amount of the frictional forces that resist its motion.
(E) There is a force being applied to the box to make it move but the external forces such as friction are not "real" forces they just resist motion.

29. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will;

(A) stop immediately.
(B) continue at a constant speed for a very short period of time and then slow to a stop.
(C) immediately start slowing to a stop.
(D) continue at a constant velocity.
(E) increase its speed for a very short period of time, then start slowing to a stop.

9

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Appendix C: A Categorical Comparison of the Force Concept Inventory Measured Variables

Newtonian Force Concepts	Common-sense Misconceptions
Beliefs accepted by scientific community	*Beliefs not-accepted by scientific community*
Correct Scores	Error Scores
Kinematics	Kinematics
First Law	Impetus
Second Law	Active Force
Third Law	Action-Reaction Pairs
Superposition of Forces	Concatenation of Influences
Other Forces	Other Influences

Appendix D: Student Background Survey

Please Note: This survey is intended to collect information to be analyzed in a educational research study. The information that you provide will be kept **confidential** and will have **no bearing** on your grade in the course. Your participation is greatly appreciated. Thank you for your help.

Course Name:______________________________ **Day & Time of Class:**__________

Name:______________________________ **Student ID #:**__________

Age:______ **Gender:**__________ **Ethnicity:**______________________________

Major/Specialization:______________________________ **Current G.P.A:**__________

Please circle your educational level at this post-secondary school:

First year Sophomore Junior Senior Fifth-year Sixth-year

How many years have you attended college?__________

Did you transfer into this university from another post-secondary school? (circle) Y / N

List the names of any science and math courses you are currently taking (including this course):

____

List the names of any science courses you have taken beyond high school (prior to this course):

____

____

List the names of any math courses you have taken beyond high school (prior to this course):

____

____

List the name, city, and state of the High School from which you received your diploma:

____

Place a check by the courses taken in high school:

Science	Math
_____Physical Science	_____AlgebraI
_____Biology I	_____Algebra II
_____Biology II	_____Trigonometry
_____AP Biology	_____Analytic Geometry
_____Chemistry I	_____Pre-Calculus
_____Chemistry II	_____Calculus
_____AP Chemistry	_____Computer Programming
_____Physics	Other:__________________
_____AP Physics	__________________

Circle the highest level of education your parents completed:

Mother	Less than high school	high school	2 yrs. college	4 yrs. college	Masters	Ph.D.
Father	Less than high school	high school	2 yrs. college	4 yrs. college	Masters	Ph.D.

Appendix E: Perception of Difficulty in Science and Math

Please Note: This survey is intended to collect information to be analyzed in a educational research study. The information that you provide will be kept **confidential** and will have **no bearing** on your grade in the course. Your participation is greatly appreciated. Thank you for your help.

Course Name:______________________________ **Day & Time of Class:**____________

Name:__________________________________ **Student ID #:**__________________

1. **Consider all of the courses you have been taking in college. How much time do you spend studying and doing homework in science?** (circle)

   Most of the time   Lot of time   no opinion   Not much time   Least time of all

2. **Consider all of the courses you have been taking in college. How much time do you spend studying and doing homework in math?** (circle)

   Most of the time   Lot of time   no opinion   Not much time   Least time of all

3. **Would you choose to take a course in science if it was not required of you?** (circle)

   Very likely   Probably   no opinion   Unlikely   Very unlikely

4. **Would you choose to take a course in math if it was not required of you?** (circle)

   Very likely   Probably   no opinion   Unlikely   Very unlikely

5. **Compared to other subjects, how difficult do you feel science is?** (circle)

   Very difficult   Fairly difficult   no opinion   Fairly easy   Very easy

6. **Compared to other subjects, how difficult do you feel math is?** (circle)

   Very difficult   Fairly difficult   no opinion   Fairly easy   Very easy

7. **How likely are you to choose to complete a college degree with an emphasis in science?**

   (circle)   Very likely   Probably   no opinion   Unlikely   Very unlikely

8. **How likely are you to choose to complete a college degree with an emphasis in math?**

   (circle)   Very likely   Probably   no opinion   Unlikely   Very unlikely

9. **Please rank the following subjects from 1 (best liked) to 5 (least liked):**

   ____Arts   ____English   ____Math   _____Physical Science   ____Social Studies

10. **Physical science is an overview (mixture) of physics, chemistry, scientific math, astromony and earth science. Please rank the following subjects from 1 (best liked) to 5 (least liked):**

    _____Astronomy   _____Chemistry   _____Earth Science   ______Physics   _____Scientific Math

Appendix F: Anxiety Questionnaire in Science and Math

Please Note: This survey is intended to collect information to be analyzed in a educational research study. The information that you provide will be kept **confidential** and will have **no bearing** on your grade in the course. Your participation is greatly appreciated. Thank you for your help.

Course Name:____________________ **Day & Time of Class:**__________

Name:____________________ **Student ID #:**__________

Instructions: When answering the questions below, imagine that you are taking a test in science or math. Indicate in the appropriate column what your feelings, attitudes, or thoughts would be. Use the following scale to answer the questions:

1 = very strongly

2 = strongly

3 = medium degree

4 = little

5 = not at all

Complete the following statement with the phrases that follow: **I would feel . . .**	Science	Math
1. . . . my heart beating fast.		
2. . . . regretful.		
3. . . . tense and my stomach would be upset.		
4. . . . that I should have studied more for that test.		
5. . . . uneasy and upset.		
6. . . . that others would be disappointed in me.		
7. . . . nervous.		
8. . . . that I may not do as well on that test as I could have.		
9. . . . panicky.		
10. . . . very confident about my performance on that test.		

Appendix G: Force Concept Inventory Score Results

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Force Concept Inventory Total Raw Score Pre-test	Physical Science 110-61	14	5.36	1.98	.53	4.21	6.50	2	10
	Physical Science 110-01	8	4.25	2.49	.88	2.17	6.33	1	7
	Physics 211-01	11	8.45	3.39	1.02	6.18	10.73	4	12
	Total	33	6.12	3.09	.54	5.03	7.22	1	12
Force Concept Inventory Total % Score Pre-test	Physical Science 110-61	14	18.4729	6.8443	1.8292	14.5212	22.4247	6.90	34.48
	Physical Science 110-01	8	14.6552	8.5960	3.0392	7.4687	21.8416	3.45	24.14
	Physics 211-01	11	29.1536	11.6798	3.5216	21.3070	37.0002	13.79	41.38
	Total	33	21.1076	10.6548	1.8548	17.3296	24.8856	3.45	41.38
Force Concept Inventory Adjusted % Score Pre-test	Physical Science 110-61	14	12.82	8.13	2.17	8.13	17.52	0	30
	Physical Science 110-01	8	12.25	9.92	3.51	3.96	20.54	0	26
	Physics 211-01	11	23.89	11.11	3.35	16.43	31.35	9	41
	Total	33	16.37	10.78	1.88	12.55	20.19	0	41
Kinematic Concepts (Correct) Pre-test	Physical Science 110-61	14	9.57	12.56	3.36	2.32	16.82	0	33
	Physical Science 110-01	8	8.50	9.09	3.21	.90	16.10	0	17
	Physics 211-01	11	18.27	21.51	6.49	3.82	32.73	0	66
	Total	33	12.21	15.68	2.73	6.65	17.77	0	66
First Law Concepts (Correct) Pre-test	Physical Science 110-61	14	20.29	14.54	3.88	11.89	28.68	0	50
	Physical Science 110-01	8	9.25	13.05	4.61	-1.66	20.16	0	38
	Physics 211-01	11	31.82	14.28	4.31	22.22	41.41	12	50
	Total	33	21.45	16.17	2.82	15.72	27.19	0	50
Second Law Concepts (Correct) Pre-test	Physical Science 110-61	14	8.93	15.83	4.23	-.21	18.07	0	50
	Physical Science 110-01	8	18.75	17.68	6.25	3.97	33.53	0	50
	Physics 211-01	11	13.64	17.19	5.18	2.09	25.18	0	50
	Total	33	12.88	16.68	2.90	6.96	18.79	0	50
Third Law Concepts (Correct) Pre-test	Physical Science 110-61	14	12.50	12.97	3.47	5.01	19.99	0	25
	Physical Science 110-01	8	12.50	18.90	6.68	-3.30	28.30	0	50
	Physics 211-01	11	31.82	31.80	9.59	10.45	53.18	0	100
	Total	33	18.94	23.41	4.08	10.64	27.24	0	100
Superposition of Forces (Correct) Pre-test	Physical Science 110-61	14	30.36	17.48	4.67	20.26	40.45	0	50
	Physical Science 110-01	8	12.50	18.90	6.68	-3.30	28.30	0	50
	Physics 211-01	11	20.45	21.85	6.59	5.78	35.13	0	75
	Total	33	22.73	20.12	3.50	15.59	29.86	0	75

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Forces (Correct) Pre-test	Physical Science 110-61	14	20.64	14.77	3.95	12.12	29.17	3	58
	Physical Science 110-01	8	13.88	12.18	4.31	3.69	24.06	0	32
	Physics 211-01	11	48.82	94.38	28.46	-14.59	112.23	3	330
	Total	33	28.39	55.92	9.73	8.56	48.22	0	330
Kinematics (Misconceptions) Pre-test	Physical Science 110-61	14	41.57	16.91	4.52	31.81	51.34	17	83
	Physical Science 110-01	8	25.00	26.55	9.39	2.80	47.20	0	83
	Physics 211-01	11	33.27	23.62	7.12	17.41	49.14	0	67
	Total	33	34.79	22.13	3.85	26.94	42.63	0	83
Impetus (Misconceptions) Pre-test	Physical Science 110-61	14	36.93	13.53	3.62	29.12	44.74	22	63
	Physical Science 110-01	8	37.00	10.69	3.78	28.06	45.94	23	58
	Physics 211-01	11	27.82	12.12	3.66	19.67	35.96	8	45
	Total	33	33.91	12.82	2.23	29.36	38.46	8	63
Active Force (Misconceptions) Pre-test	Physical Science 110-61	14	29.00	14.32	3.83	20.73	37.27	4	45
	Physical Science 110-01	8	16.13	8.22	2.91	9.25	23.00	0	25
	Physics 211-01	11	17.64	8.69	2.62	11.80	23.47	0	29
	Total	33	22.09	12.58	2.19	17.63	26.55	0	45
Action Reaction Pairs (Misconceptions) Pre-test	Physical Science 110-61	14	38.29	12.91	3.45	30.83	45.74	25	62
	Physical Science 110-01	8	34.88	20.94	7.40	17.37	52.38	12	67
	Physics 211-01	11	39.73	23.59	7.11	23.88	55.57	0	75
	Total	33	37.94	18.47	3.21	31.39	44.49	0	75
Concantenation of Influences (Misconceptions) Pre-test	Physical Science 110-61	14	23.50	10.39	2.78	17.50	29.50	0	38
	Physical Science 110-01	8	29.63	14.75	5.22	17.29	41.96	7	50
	Physics 211-01	11	28.73	9.42	2.84	22.40	35.06	17	42
	Total	33	26.73	11.28	1.96	22.73	30.73	0	50
Other Influences (Misconceptions) Pre-test	Physical Science 110-61	14	29.71	10.02	2.68	23.93	35.50	12	46
	Physical Science 110-01	8	29.63	10.78	3.81	20.61	38.64	7	43
	Physics 211-01	11	25.55	11.40	3.44	17.89	33.20	7	47
	Total	33	28.30	10.52	1.83	24.57	32.03	7	47
Force Concept Inventory Total Raw Score Post-test	Physical Science 110-61	14	8.50	1.91	.51	7.40	9.60	4	12
	Physical Science 110-01	8	7.75	2.96	1.05	5.27	10.23	4	12
	Physics 211-01	11	11.18	2.60	.78	9.43	12.93	8	17
	Total	33	9.21	2.76	.48	8.23	10.19	4	17

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Force Concept Inventory Total % Score Post-test	Physical Science 110-61	14	29.3103	6.5914	1.7616	25.5046	33.1161	13.79	41.38
	Physical Science 110-01	8	26.7241	10.2209	3.6136	18.1792	35.2691	13.79	41.38
	Physics 211-01	11	38.5580	8.9679	2.7039	32.5333	44.5827	27.59	58.62
	Total	33	31.7659	9.5124	1.6559	28.3930	35.1389	13.79	58.62
Force Concept Inventory Adjusted % Score Post-test	Physical Science 110-61	14	26.1250	9.8663	2.6369	20.4284	31.8216	3.00	43.75
	Physical Science 110-01	8	21.2500	10.8463	3.8348	12.1822	30.3178	3.00	32.50
	Physics 211-01	11	31.4545	12.6179	3.8044	22.9778	39.9313	12.50	55.25
	Total	33	26.7197	11.4181	1.9876	22.6710	30.7684	3.00	55.25
Kinematic Concepts (Correct) Post-test	Physical Science 110-61	14	18.00	13.74	3.67	10.07	25.93	0	50
	Physical Science 110-01	8	8.50	9.09	3.21	.90	16.10	0	17
	Physics 211-01	11	21.09	14.90	4.49	11.08	31.10	0	33
	Total	33	16.73	13.72	2.39	11.86	21.59	0	50
First Law Concepts (Correct) Post-test	Physical Science 110-61	14	29.36	16.21	4.33	20.00	38.72	12	50
	Physical Science 110-01	8	29.63	16.36	5.78	15.95	43.30	12	62
	Physics 211-01	11	43.36	14.87	4.48	33.38	53.35	25	62
	Total	33	34.09	16.70	2.91	28.17	40.01	12	62
Second Law Concepts (Correct) Post-test	Physical Science 110-61	14	28.57	19.26	5.15	17.45	39.69	0	50
	Physical Science 110-01	8	21.88	16.02	5.66	8.48	35.27	0	50
	Physics 211-01	11	20.45	21.85	6.59	5.78	35.13	0	50
	Total	33	24.24	19.25	3.35	17.42	31.07	0	50
Third Law Concepts (Correct) Post-test	Physical Science 110-61	14	28.57	23.73	6.34	14.87	42.27	0	75
	Physical Science 110-01	8	25.00	18.90	6.68	9.20	40.80	0	50
	Physics 211-01	11	40.91	32.16	9.70	19.31	62.51	0	100
	Total	33	31.82	25.98	4.52	22.61	41.03	0	100
Superposition of Forces (Correct) Post-test	Physical Science 110-61	14	23.21	18.25	4.88	12.68	33.75	0	50
	Physical Science 110-01	8	25.00	13.36	4.72	13.83	36.17	0	50
	Physics 211-01	11	27.27	20.78	6.27	13.31	41.23	0	50
	Total	33	25.00	17.68	3.08	18.73	31.27	0	50
Forces (Correct) Post-test	Physical Science 110-61	14	23.86	11.52	3.08	17.20	30.51	12	47
	Physical Science 110-01	8	27.50	12.02	4.25	17.45	37.55	8	40
	Physics 211-01	11	35.09	15.51	4.68	24.67	45.51	12	57
	Total	33	28.48	13.61	2.37	23.66	33.31	8	57

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Kinematics (Misconceptions) Post-test	Physical Science 110-61	14	37.93	12.21	3.26	30.88	44.98	17	67
	Physical Science 110-01	8	41.63	26.68	9.43	19.32	63.93	0	83
	Physics 211-01	11	30.18	23.22	7.00	14.58	45.78	0	83
	Total	33	36.24	20.15	3.51	29.10	43.39	0	83
Impetus (Misconceptions) Post-test	Physical Science 110-61	14	32.21	8.78	2.35	27.14	37.28	15	45
	Physical Science 110-01	8	31.25	4.10	1.45	27.82	34.68	27	40
	Physics 211-01	11	21.18	10.72	3.23	13.98	28.39	8	40
	Total	33	28.30	9.86	1.72	24.81	31.80	8	45
Active Force (Misconceptions) Post-test	Physical Science 110-61	14	21.00	13.55	3.62	13.17	28.83	2	50
	Physical Science 110-01	8	19.75	15.27	5.40	6.99	32.51	0	36
	Physics 211-01	11	22.64	12.15	3.66	14.47	30.80	4	40
	Total	33	21.24	13.15	2.29	16.58	25.91	0	50
Action Reaction Pairs (Misconceptions) Post-test	Physical Science 110-61	14	31.79	18.26	4.88	21.25	42.33	0	58
	Physical Science 110-01	8	39.00	15.29	5.41	26.22	51.78	17	58
	Physics 211-01	11	33.64	22.21	6.70	18.72	48.56	0	75
	Total	33	34.15	18.68	3.25	27.53	40.78	0	75
Concantenation of Influences (Misconceptions) Post-test	Physical Science 110-61	14	31.21	12.94	3.46	23.74	38.68	8	55
	Physical Science 110-01	8	23.63	13.96	4.94	11.96	35.29	7	48
	Physics 211-01	11	35.27	12.17	3.67	27.10	43.45	15	57
	Total	33	30.73	13.29	2.31	26.01	35.44	7	57
Other Influences (Misconceptions) Post-test	Physical Science 110-61	14	22.93	8.07	2.16	18.27	27.59	8	33
	Physical Science 110-01	8	21.38	7.71	2.73	14.93	27.82	12	35
	Physics 211-01	11	26.09	8.07	2.43	20.67	31.51	10	41
	Total	33	23.61	7.96	1.39	20.78	26.43	8	41
Force Concept Inventory Score Change	Physical Science 110-61	14	47.43	35.92	9.60	26.70	68.17	0	111
	Physical Science 110-01	8	67.73	35.69	12.62	37.89	97.57	13	120
	Physics 211-01	11	32.41	39.81	12.00	5.66	59.16	-18	106
	Total	33	47.35	38.46	6.69	33.71	60.98	-18	120

	Levene Statistic	df1	df2	Sig.
Force Concept Inventory Total Raw Score Pre-test	3.309	2	30	.050
Force Concept Inventory Total % Score Pre-test	3.309	2	30	.050
Force Concept Inventory Adjusted % Score Pre-test	1.305	2	30	.286
Kinematic Concepts (Correct) Pre-test	.952	2	30	.397
First Law Concepts (Correct) Pre-test	.312	2	30	.734
Second Law Concepts (Correct) Pre-test	.203	2	30	.817
Third Law Concepts (Correct) Pre-test	2.537	2	30	.096
Superposition of Forces (Correct) Pre-test	.049	2	30	.952
Forces (Correct) Pre-test	2.938	2	30	.068
Kinematics (Misconceptions) Pre-test	.616	2	30	.547
Impetus (Misconceptions) Pre-test	.663	2	30	.523
Active Force (Misconceptions) Pre-test	3.088	2	30	.060
Action Reaction Pairs (Misconceptions) Pre-test	1.952	2	30	.160
Concantenation of Influences (Misconceptions) Pre-test	.750	2	30	.481
Other Influences (Misconceptions) Pre-test	.136	2	30	.873
Force Concept Inventory Total Raw Score Post-test	1.473	2	30	.245
Force Concept Inventory Total % Score Post-test	1.473	2	30	.245
Force Concept Inventory Adjusted % Score Post-test	.239	2	30	.789
Kinematic Concepts (Correct) Post-test	1.170	2	30	.324
First Law Concepts (Correct) Post-test	.236	2	30	.791
Second Law Concepts (Correct) Post-test	1.216	2	30	.311
Third Law Concepts (Correct) Post-test	2.096	2	30	.141
Superposition of Forces (Correct) Post-test	1.816	2	30	.180
Forces (Correct) Post-test	.513	2	30	.604
Kinematics (Misconceptions) Post-test	2.202	2	30	.128

	Levene Statistic	df1	df2	Sig.
Impetus (Misconceptions) Post-test	3.167	2	30	.057
Active Force (Misconceptions) Post-test	.630	2	30	.539
Action Reaction Pairs (Misconceptions) Post-test	.391	2	30	.680
Concantenation of Influences (Misconceptions) Post-test	.125	2	30	.883
Other Influences (Misconceptions) Post-test	.194	2	30	.824
Force Concept Inventory Score Change	.036	2	30	.965

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Force Concept Inventory Total Raw Score Pre-test	Between Groups	96.074	2	48.037	6.881	.003
	Within Groups	209.442	30	6.981		
	Total	305.515	32			
Force Concept Inventory Total % Score Pre-test	Between Groups	1142.373	2	571.187	6.881	.003
	Within Groups	2490.387	30	83.013		
	Total	3632.760	32			
Force Concept Inventory Adjusted % Score Pre-test	Between Groups	933.541	2	466.771	5.033	.013
	Within Groups	2782.474	30	92.749		
	Total	3716.015	32			
Kinematic Concepts (Correct) Pre-test	Between Groups	611.905	2	305.952	1.265	.297
	Within Groups	7257.610	30	241.920		
	Total	7869.515	32			
First Law Concepts (Correct) Pre-test	Between Groups	2392.188	2	1196.094	6.002	.006
	Within Groups	5977.994	30	199.266		
	Total	8370.182	32			
Second Law Concepts (Correct) Pre-test	Between Groups	500.541	2	250.271	.894	.420
	Within Groups	8400.974	30	280.032		
	Total	8901.515	32			
Third Law Concepts (Correct) Pre-test	Between Groups	2736.742	2	1368.371	2.774	.078
	Within Groups	14801.136	30	493.371		
	Total	17537.879	32			
Superposition of Forces (Correct) Pre-test	Between Groups	1708.604	2	854.302	2.279	.120
	Within Groups	11245.942	30	374.865		
	Total	12954.545	32			
Forces (Correct) Pre-test	Between Groups	7116.153	2	3558.077	1.148	.331
	Within Groups	92957.726	30	3098.591		
	Total	100073.879	32			
Kinematics (Misconceptions) Pre-test	Between Groups	1435.905	2	717.952	1.514	.236
	Within Groups	14229.610	30	474.320		
	Total	15665.515	32			
Impetus (Misconceptions) Pre-test	Between Groups	612.162	2	306.081	1.975	.156
	Within Groups	4648.565	30	154.952		
	Total	5260.727	32			

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Active Force (Misconceptions) Pre-test	Between Groups	1171.307	2	585.653	4.513	.019
	Within Groups	3893.420	30	129.781		
	Total	5064.727	32			
Action Reaction Pairs (Misconceptions) Pre-test	Between Groups	111.965	2	55.982	.156	.857
	Within Groups	10799.914	30	359.997		
	Total	10911.879	32			
Concantenation of Influences (Misconceptions) Pre-test	Between Groups	256.989	2	128.494	1.010	.376
	Within Groups	3815.557	30	127.185		
	Total	4072.545	32			
Other Influences (Misconceptions) Pre-test	Between Groups	125.510	2	62.755	.551	.582
	Within Groups	3417.459	30	113.915		
	Total	3542.970	32			
Force Concept Inventory Total Raw Score Post-test	Between Groups	66.879	2	33.439	5.679	.008
	Within Groups	176.636	30	5.888		
	Total	243.515	32			
Force Concept Inventory Total % Score Post-test	Between Groups	795.229	2	397.615	5.679	.008
	Within Groups	2100.313	30	70.010		
	Total	2895.543	32			
Force Concept Inventory Adjusted % Score Post-test	Between Groups	490.899	2	245.449	2.000	.153
	Within Groups	3681.071	30	122.702		
	Total	4171.970	32			
Kinematic Concepts (Correct) Post-test	Between Groups	773.636	2	386.818	2.210	.127
	Within Groups	5250.909	30	175.030		
	Total	6024.545	32			
First Law Concepts (Correct) Post-test	Between Groups	1419.093	2	709.546	2.838	.074
	Within Groups	7501.635	30	250.054		
	Total	8920.727	32			
Second Law Concepts (Correct) Post-test	Between Groups	465.030	2	232.515	.612	.549
	Within Groups	11391.031	30	379.701		
	Total	11856.061	32			
Third Law Concepts (Correct) Post-test	Between Groups	1428.571	2	714.286	1.063	.358
	Within Groups	20162.338	30	672.078		
	Total	21590.909	32			

Appendix H: Perception of Difficulty Results

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Superposition of Forces (Correct) Post-test	Between Groups	101.461	2	50.731	.154	.858
	Within Groups	9898.539	30	329.951		
	Total	10000.000	32			
Forces (Correct) Post-test	Between Groups	787.619	2	393.810	2.297	.118
	Within Groups	5142.623	30	171.421		
	Total	5930.242	32			
Kinematics (Misconceptions) Post-test	Between Groups	675.621	2	337.810	.823	.449
	Within Groups	12314.440	30	410.481		
	Total	12990.061	32			
Impetus (Misconceptions) Post-test	Between Groups	841.476	2	420.738	5.562	.009
	Within Groups	2269.494	30	75.650		
	Total	3110.970	32			
Active Force (Misconceptions) Post-test	Between Groups	40.015	2	20.008	.109	.897
	Within Groups	5496.045	30	183.202		
	Total	5536.061	32			
Action Reaction Pairs (Misconceptions) Post-test	Between Groups	269.340	2	134.670	.371	.693
	Within Groups	10900.903	30	363.363		
	Total	11170.242	32			
Concantenation of Influences (Misconceptions) Post-test	Between Groups	634.131	2	317.066	1.895	.168
	Within Groups	5020.414	30	167.347		
	Total	5654.545	32			
Other Influences (Misconceptions) Post-test	Between Groups	114.166	2	57.083	.895	.419
	Within Groups	1913.713	30	63.790		
	Total	2027.879	32			
Force Concept Inventory Score Change	Between Groups	5778.442	2	2889.221	2.086	.142
	Within Groups	41542.818	30	1384.761		
	Total	47321.260	32			

Appendix H: Perception of Difficulty Results

Class Code: Total

	Mean	Std. Deviation	Median	Minimum	Maximum	Std. Error of Mean	Variance
Likely to do science homework?	2.7917	1.1101	2.0000	Most of the time	Least time of all	.1602	1.232
Likely to do math homework?	2.7500	1.1760	2.0000	Most of the time	Least time of all	.1697	1.383
Likely to take science courses?	3.0417	1.3362	2.0000	Very likely	Very unlikely	.1929	1.785
Likely to take math courses?	2.6458	1.4065	2.0000	Very likely	Very unlikely	.2030	1.978
Perception of science difficulty	3.3542	1.1202	4.0000	Very difficult	Very easy	.1617	1.255
Perception of math difficulty	3.2500	1.2116	4.0000	Very difficult	Very easy	.1749	1.468
Likely to earn a science-emphasis degree?	3.0833	1.5957	3.5000	Very likely	Very unlikely	.2303	2.546
Likely to earn a math-emphasis science degree?	3.1458	1.5157	4.0000	Very likely	Very unlikely	.2188	2.297
Arts	2.8125	1.5527	2.5000	1.00	5.00	.2241	2.411
English	2.5833	1.4415	2.0000	1.00	5.00	.2081	2.078
Math	3.0417	1.5568	3.0000	1.00	5.00	.2247	2.424
Physical Science	3.1667	1.4192	3.0000	1.00	5.00	.2048	2.014
Social Studies	3.4167	1.3501	4.0000	1.00	5.00	.1949	1.823
Astronomy	3.6250	3.0640	3.5000	1.00	22.00	.4423	9.388
Chemistry	3.2292	1.5743	3.0000	1.00	5.00	.2272	2.478
Earth Science	2.8750	1.4964	3.0000	1.00	5.00	.2160	2.239
Physics	3.0417	1.4136	3.0000	1.00	5.00	.2040	1.998
Scientific Math	2.8958	1.4621	3.0000	1.00	5.00	.2110	2.138
Perception of Science Difficulty Score	10.6875	4.3670	9.5000	4.00	20.00	.6303	19.070
Perception of Math Difficulty Score	9.9792	4.5779	10.0000	.00	19.00	.6608	20.957

Appendix I: Anxiety in Science Results

Class Code: Total

	Mean	Std. Deviation	Median	Minimum	Maximum	Std. Error of Mean	Variance
...my heart beating fast.	3.1458	1.4290	3.0000	Very strongly	Not at all	.2063	2.042
...regretful.	3.8542	1.3989	4.5000	Very strongly	Not at all	.2019	1.957
...tense and my stomach would be upset.	3.6250	1.3934	4.0000	Very strongly	Not at all	.2011	1.941
...that I should have studied more for the test.	2.6042	1.1803	2.0000	Very strongly	Not at all	.1704	1.393
...uneasy and upset.	3.6250	1.3625	4.0000	Very strongly	Not at all	.1967	1.856
...that others would be disappointed in me.	4.0208	1.1758	4.5000	Very strongly	Not at all	.1697	1.383
...nervous	3.0417	1.4136	3.0000	Very strongly	Not at all	.2040	1.998
...that I may not do as well on that test as I could have.	2.7708	1.1713	3.0000	Very strongly	Not at all	.1691	1.372
...panicky.	3.5833	1.4267	4.0000	Very strongly	Not at all	.2059	2.035
...very confident about my performance on that test.	2.9583	1.1843	3.0000	Very strongly	Not at all	.1709	1.402
Anxiety of Science Score	23.2292	9.4266	25.5000	1.00	39.00	1.3606	88.861

Appendix J: Anxiety in Math Results

Class Code: Total

	Mean	Std. Deviation	Median	Minimum	Maximum	Std. Error of Mean	Variance
...my heart beating fast.	3.1458	1.3682	3.0000	Very strongly	Not at all	.1975	1.872
...regretful.	3.9583	1.3040	4.5000	Very strongly	Not at all	.1882	1.700
...tense and my stomach would be upset.	3.7708	1.2922	4.0000	Very strongly	Not at all	.1865	1.670
..that I should have studied more for that test.	2.6250	1.2138	2.0000	Very strongly	Not at all	.1752	1.473
...uneasy and upset.	3.6458	1.4065	4.0000	Very strongly	Not at all	.2030	1.978
....that others would be disappointed in me.	4.0833	1.1077	4.5000	Very strongly	Not at all	.1599	1.227
...nervous.	3.0417	1.3832	3.0000	Very strongly	Not at all	.1996	1.913
...that I may not do as well on that test as I could have.	2.8125	1.2318	3.0000	Very strongly	Not at all	.1778	1.517
...panicky.	3.7500	1.3605	4.0000	Very strongly	Not at all	.1964	1.851
...very confident about my performance on that test.	3.2083	1.2021	3.0000	Very strongly	Not at all	.1735	1.445
Anxiety in Math Score	24.0417	9.1441	25.0000	5.00	40.00	1.3198	83.615

Appendix K: ANOVA Analysis on Quality of Instruction

		Sum of Squares	df	Mean Square	F	Sig.
Force Concept Inventory Total Score Pre-test	Between Groups	1142.373	2	571.187	6.881	.003
	Within Groups	2490.387	30	83.013		
	Total	3632.760	32			
Force Concept Inventory Adjusted Score Pre-test	Between Groups	933.541	2	466.771	5.033	.013
	Within Groups	2782.474	30	92.749		
	Total	3716.015	32			
Force Concept Inventory Total Score Post-test	Between Groups	795.229	2	397.615	5.679	.008
	Within Groups	2100.313	30	70.010		
	Total	2895.543	32			
Force Concept Inventory Adjusted Score Post-test	Between Groups	490.899	2	245.449	2.000	.153
	Within Groups	3681.071	30	122.702		
	Total	4171.970	32			
Force Concept Inventory Score Change	Between Groups	5778.442	2	2889.221	2.086	.142
	Within Groups	41542.818	30	1384.761		
	Total	47321.260	32			

Appendix L: Descriptive Statistics of Course Background, Parental Education, and Force Concept Inventory Scores

	Mean	Std. Deviation	N
Number of post-high school science courses	2.1000	1.8071	30
Number of post-high school math courses	2.6667	2.0229	30
Number of high school science courses	2.5667	1.5906	30
Number of high school physics courses	.4333	.6261	30
Number of high school math courses	3.1333	1.6761	30
Number of high school algebra courses	1.6667	.4795	30
Mother's Education Level	12.7333	3.2582	30
Father's Education Level	12.4667	2.9094	30
Force Concept Inventory Total Score Pre-test	20.8046	10.4231	30
Force Concept Inventory Adjusted Score Pre-test	16.10	10.64	30
Force Concept Inventory Total Score Post-test	31.4943	9.9089	30
Force Concept Inventory Adjusted Score Post-test	26.6833	11.7581	30
Force Concept Inventory Score Change	47.62	37.78	30

Appendix M: Pearson Correlations: Course Background, Parental Education, and Force Concept Inventory Scores

		Number of post-high school science courses	Number of post-high school math courses	Number of high school science courses	Number of high school physics courses	Number of high school math courses	Number of high school algebra courses	Mother's Education Level
Number of post-high school science courses	Pearson Correlation	1.000	.500**	.208	.082	.212	-.159	.514**
	Sig. (2-tailed)	.	.005	.271	.666	.261	.401	.004
	Sum of Squares and Cross-products	94.700	53.000	17.300	2.700	18.600	-4.000	87.800
	Covariance	3.266	1.828	.597	9.310E-02	.641	-.138	3.028
Number of post-high school math courses	Pearson Correlation	.500**	1.000	.093	.064	.197	.095	.488**
	Sig. (2-tailed)	.005	.	.625	.739	.298	.618	.006
	Sum of Squares and Cross-products	53.000	118.667	8.667	2.333	19.333	2.667	93.333
	Covariance	1.828	4.092	.299	8.046E-02	.667	9.195E-02	3.218
Number of high school science courses	Pearson Correlation	.208	.093	1.000	.680**	.540**	.166	.143
	Sig. (2-tailed)	.271	.625	.	.000	.002	.381	.450
	Sum of Squares and Cross-products	17.300	8.667	73.367	19.633	41.733	3.667	21.533
	Covariance	.597	.299	2.530	.677	1.439	.126	.743
Number of high school physics courses	Pearson Correlation	.082	.064	.680**	1.000	.469**	.153	-.094
	Sig. (2-tailed)	.666	.739	.000	.	.009	.419	.623
	Sum of Squares and Cross-products	2.700	2.333	19.633	11.367	14.267	1.333	-5.533
	Covariance	9.310E-02	8.046E-02	.677	.392	.492	4.598E-02	-.191
Number of high school math courses	Pearson Correlation	.212	.197	.540**	.469**	1.000	.701**	.335
	Sig. (2-tailed)	.261	.298	.002	.009	.	.000	.070
	Sum of Squares and Cross-products	18.600	19.333	41.733	14.267	81.467	16.333	53.067
	Covariance	.641	.667	1.439	.492	2.809	.563	1.830
Number of high school algebra courses	Pearson Correlation	-.159	.095	.166	.153	.701**	1.000	.250
	Sig. (2-tailed)	.401	.618	.381	.419	.000	.	.182
	Sum of Squares and Cross-products	-4.000	2.667	3.667	1.333	16.333	6.667	11.333
	Covariance	-.138	9.195E-02	.126	4.598E-02	.563	.230	.391

		Number of post-high school science courses	Number of post-high school math courses	Number of high school science courses	Number of high school physics courses	Number of high school math courses	Number of high school algebra courses	Mother's Education Level
Mother's Education Level	Pearson Correlation	.514**	.488**	.143	-.094	.335	.250	1.000
	Sig. (2-tailed)	.004	.006	.450	.623	.070	.182	.
	Sum of Squares and Cross-products	87.800	93.333	21.533	-5.533	53.067	11.333	307.867
	Covariance	3,028	3,218	.743	-.191	1.830	.391	10.616
Father's Education Level	Pearson Correlation	.437*	.379*	.209	.037	.185	.066	.748**
	Sig. (2-tailed)	.016	.039	.267	.848	.328	.729	.000
	Sum of Squares and Cross-products	66.600	64.667	28.067	1.933	26.133	2.667	205.733
	Covariance	2.297	2.230	.968	6.667E-02	.901	9.195E-02	7.094
Force Concept Inventory Total Score Pre-test	Pearson Correlation	.094	.227	.290	.284	.407*	.436*	.215
	Sig. (2-tailed)	.621	.227	.120	.129	.025	.016	.255
	Sum of Squares and Cross-products	51.379	139.080	139.425	53.678	206.437	63.218	211.264
	Covariance	1.772	4.796	4.808	1.851	7.119	2.180	7.285
Force Concept Inventory Adjusted Score Pre-test	Pearson Correlation	.085	.215	.149	.067	.379*	.455*	.322
	Sig. (2-tailed)	.655	.255	.432	.725	.039	.012	.083
	Sum of Squares and Cross-products	47.450	134.000	73.050	12.950	196.100	67.250	323.800
	Covariance	1.636	4.621	2.519	.447	6.762	2.319	11.166
Force Concept Inventory Total Score Post-test	Pearson Correlation	.270	.221	.073	.235	.261	.284	.063
	Sig. (2-tailed)	.150	.240	.700	.211	.163	.129	.741
	Sum of Squares and Cross-products	140.000	128.736	33.563	42.299	125.747	39.080	58.851
	Covariance	4.828	4.439	1.157	1.459	4.336	1.348	2.029
Force Concept Inventory Adjusted Score Post-test	Pearson Correlation	.119	.271	-.062	.140	.217	.270	.100
	Sig. (2-tailed)	.530	.148	.745	.461	.250	.150	.598
	Sum of Squares and Cross-products	73.450	186.583	-33.617	29.867	123.767	44.083	111.467
	Covariance	2.533	6.434	-1.159	1.030	4.268	1.520	3.844

		Number of post-high school science courses	Number of post-high school math courses	Number of high school science courses	Number of high school physics courses	Number of high school math courses	Number of high school algebra courses	Mother's Education Level
Force Concept Inventory Score Change	Pearson Correlation	.118	-.149	-.268	-.204	-.334	-.294	-.118
	Sig. (2-tailed)	.533	.431	.152	.279	.071	.115	.533
	Sum of Squares and Cross-products	234.442	-330.961	-467.583	-139.999	-612.863	-154.250	-422.375
	Covariance	8.084	-11.412	-16.124	-4.828	-21.133	-5.319	-14.565

		Father's Education Level	Force Concept Inventory Total Score Pre-test	Force Concept Inventory Adjusted Score Pre-test	Force Concept Inventory Total Score Post-test	Force Concept Inventory Adjusted Score Post-test	Force Concept Inventory Score Change
Number of post-high school science courses	Pearson Correlation	.437*	.094	.085	.270	.119	.118
	Sig. (2-tailed)	.016	.621	.655	.150	.530	.533
	Sum of Squares and Cross-products	66.600	51.379	47.450	140.000	73.450	234.442
	Covariance	2.297	1.772	1.636	4.828	2.533	8.084
Number of post-high school math courses	Pearson Correlation	.379*	.227	.215	.221	.271	-.149
	Sig. (2-tailed)	.039	.227	.255	.240	.148	.431
	Sum of Squares and Cross-products	64.667	139.080	134.000	128.736	186.583	-330.961
	Covariance	2.230	4.796	4.621	4.439	6.434	-11.412
Number of high school science courses	Pearson Correlation	.209	.290	.149	.073	-.062	-.268
	Sig. (2-tailed)	.267	.120	.432	.700	.745	.152
	Sum of Squares and Cross-products	28.067	139.425	73.050	33.563	-33.617	-467.583
	Covariance	.968	4.808	2.519	1.157	-1.159	-16.124
Number of high school physics courses	Pearson Correlation	.037	.284	.067	.235	.140	-.204
	Sig. (2-tailed)	.848	.129	.725	.211	.461	.279
	Sum of Squares and Cross-products	1.933	53.678	12.950	42.299	29.867	-139.999
	Covariance	6.667E-02	1.851	.447	1.459	1.030	-4.828
Number of high school math courses	Pearson Correlation	.185	.407*	.379*	.261	.217	-.334
	Sig. (2-tailed)	.328	.025	.039	.163	.250	.071
	Sum of Squares and Cross-products	26.133	206.437	196.100	125.747	123.767	-612.863
	Covariance	.901	7.119	6.762	4.336	4.268	-21.133
Number of high school algebra courses	Pearson Correlation	.066	.436*	.455*	.284	.270	-.294
	Sig. (2-tailed)	.729	.016	.012	.129	.150	.115
	Sum of Squares and Cross-products	2.667	63.218	67.250	39.080	44.083	-154.250
	Covariance	9.195E-02	2.180	2.319	1.348	1.520	-5.319

		Father's Education Level	Force Concept Inventory Total Score Pre-test	Force Concept Inventory Adjusted Score Pre-test	Force Concept Inventory Total Score Post-test	Force Concept Inventory Adjusted Score Post-test	Force Concept Inventory Score Change
Mother's Education Level	Pearson Correlation	.748**	.215	.322	.063	.100	-.118
	Sig. (2-tailed)	.000	.255	.083	.741	.598	.533
	Sum of Squares and Cross-products	205.733	211.264	323.800	58.851	111.467	-422.375
	Covariance	7.094	7.285	11.166	2.029	3.844	-14.565
Father's Education Level	Pearson Correlation	1.000	-.025	.187	-.090	.060	.088
	Sig. (2-tailed)	.	.894	.323	.636	.753	.644
	Sum of Squares and Cross-products	245.467	-22.299	167.600	-75.402	59.433	280.183
	Covariance	8.464	-.769	5.779	-2.600	2.049	9.661
Force Concept Inventory Total Score Pre-test	Pearson Correlation	-.025	1.000	.749**	.698**	.499**	-.771**
	Sig. (2-tailed)	.894	.	.000	.000	.005	.000
	Sum of Squares and Cross-products	-22.299	3150.614	2409.138	2091.161	1774.368	-8803.492
	Covariance	-.769	108.642	83.074	72.109	61.185	-303.569
Force Concept Inventory Adjusted Score Pre-test	Pearson Correlation	.187	.749**	1.000	.448*	.441*	-.667**
	Sig. (2-tailed)	.323	.000	.	.013	.015	.008
	Sum of Squares and Cross-products	167.600	2409.138	3282.200	1369.310	1599.450	-7774.648
	Covariance	5.779	83.074	113.179	47.218	55.153	-268.091
Force Concept Inventory Total Score Post-test	Pearson Correlation	-.090	.698**	.448*	1.000	.759**	-.164
	Sig. (2-tailed)	.636	.000	.013	.	.000	.388
	Sum of Squares and Cross-products	-75.402	2091.161	1369.310	2847.404	2565.575	-1776.449
	Covariance	-2.600	72.109	47.218	98.186	88.468	-61.257
Force Concept Inventory Adjusted Score Post-test	Pearson Correlation	.060	.499**	.441*	.759**	1.000	-.101
	Sig. (2-tailed)	.753	.005	.015	.000	.	.594
	Sum of Squares and Cross-products	59.433	1774.368	1599.450	2565.575	4009.367	-1305.162
	Covariance	2.049	61.185	55.153	88.468	138.254	-45.006

		Father's Education Level	Force Concept Inventory Total Score Pre-test	Force Concept Inventory Adjusted Score Pre-test	Force Concept Inventory Total Score Post-test	Force Concept Inventory Adjusted Score Post-test	Force Concept Inventory Score Change
Force Concept Inventory Score Change	Pearson Correlation	.088	-.771**	-.667**	-.164	-.101	1.000
	Sig. (2-tailed)	.644	.000	.000	.388	.594	.
	Sum of Squares and Cross-products	280.183	-8803.492	-7774.648	-1776.449	-1305.162	41385.527
	Covariance	9.661	-303.569	-268.091	-61.257	-45.006	1427.087

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Listwise N=30

Appendix N: Descriptive Statistics of Perception of Difficulty, Anxiety, Parental Education Level, and Force Concept Inventory Scores

	Mean	Std. Deviation	N
Perception of Science Difficulty Score	10.9000	4.6635	30
Perception of Math Difficulty Score	10.0000	3.8237	30
Anxiety of Science Score	21.0333	10.0875	30
Anxiety in Math Score	22.5667	9.6013	30
Force Concept Inventory Total Score Pre-test	20.8046	10.4231	30
Force Concept Inventory Adjusted Score Pre-test	16.10	10.64	30
Force Concept Inventory Total Score Post-test	31.4943	9.9089	30
Force Concept Inventory Adjusted Score Post-test	26.6833	11.7581	30
Force Concept Inventory Score Change	47.62	37.78	30
Mother's Education Level	12.7333	3.2582	30
Father's Education Level	12.4667	2.9094	30

Appendix O: Pearson Correlations: Perception of Difficulty, Anxiety, Parental Education Level, and Force Concept Inventory Scores

		Perception of Science Difficulty Score	Perception of Math Difficulty Score	Anxiety of Science Score	Anxiety in Math Score	Force Concept Inventory Total Score Pre-test	Force Concept Inventory Adjusted Score Pre-test	Force Concept Inventory Total Score Post-test
Perception of Science Difficulty Score	Pearson Correlation	1.000	-.095	-.435*	-.002	-.235	-.012	-.213
	Sig. (2-tailed)	.	.618	.016	.993	.212	.949	.259
	Sum of Squares and Cross-products	630.700	-49.000	-592.900	-2.300	-330.690	-17.700	-284.828
	Covariance	21.748	-1.690	-20.445	-7.931E-02	-11.403	-.610	-9.822
Perception of Math Difficulty Score	Pearson Correlation	-.095	1.000	-.102	-.541**	-.307	-.241	-.119
	Sig. (2-tailed)	.618	.	.592	.002	.099	.199	.530
	Sum of Squares and Cross-products	-49.000	424.000	-114.000	-576.000	-355.172	-284.500	-131.034
	Covariance	-1.690	14.621	-3.931	-19.862	-12.247	-9.810	-4.518
Anxiety of Science Score	Pearson Correlation	-.435*	-.102	1.000	.525**	.383*	.192	.162
	Sig. (2-tailed)	.016	.592	.	.003	.037	.309	.394
	Sum of Squares and Cross-products	-592.900	-114.000	2950.967	1474.433	1168.851	597.650	468.506
	Covariance	-20.445	-3.931	101.757	50.843	40.305	20.609	16.155
Anxiety in Math Score	Pearson Correlation	-.002	-.541**	.525**	1.000	.271	.175	.086
	Sig. (2-tailed)	.993	.002	.003	.	.147	.355	.652
	Sum of Squares and Cross-products	-2.300	-576.000	1474.433	2673.367	787.701	518.800	237.011
	Covariance	-7.931E-02	-19.862	50.843	92.185	27.162	17.890	8.173
Force Concept Inventory Total Score Pre-test	Pearson Correlation	-.235	-.307	.383*	.271	1.000	.749**	.698**
	Sig. (2-tailed)	.212	.099	.037	.147	.	.000	.000
	Sum of Squares and Cross-products	-330.690	-355.172	1168.851	787.701	3150.614	2409.138	2091.161
	Covariance	-11.403	-12.247	40.305	27.162	108.642	83.074	72.109
Force Concept Inventory Adjusted Score Pre-test	Pearson Correlation	-.012	-.241	.192	.175	.749**	1.000	.448*
	Sig. (2-tailed)	.949	.199	.309	.355	.000	.	.013
	Sum of Squares and Cross-products	-17.700	-284.500	597.650	518.800	2409.138	3282.200	1369.310
	Covariance	-.610	-9.810	20.609	17.890	83.074	113.179	47.218

		Perception of Science Difficulty Score	Perception of Math Difficulty Score	Anxiety of Science Score	Anxiety in Math Score	Force Concept Inventory Total Score Pre-test	Force Concept Inventory Adjusted Score Pre-test	Force Concept Inventory Total Score Post-test
Force Concept Inventory Total Score Post-test	Pearson Correlation	-.213	-.119	.162	.086	.698**	.448*	1.000
	Sig. (2-tailed)	.259	.530	.394	.652	.000	.013	.
	Sum of Squares and Cross-products	-284.828	-131.034	468.506	237.011	2091.161	1369.310	2847.404
	Covariance	-9.822	-4.518	16.155	8.173	72.109	47.218	98.186
Force Concept Inventory Adjusted Score Post-test	Pearson Correlation	-.112	-.167	-.008	-.022	.499**	.441*	.759**
	Sig. (2-tailed)	.554	.377	.967	.907	.005	.015	.000
	Sum of Squares and Cross-products	-178.700	-218.000	-27.433	-72.617	1774.368	1599.450	2565.575
	Covariance	-6.162	-7.517	-.946	-2.504	61.185	55.153	88.468
Force Concept Inventory Score Change	Pearson Correlation	.080	.253	-.300	-.227	-.771**	-.667**	-.164
	Sig. (2-tailed)	.674	.177	.107	.227	.000	.000	.388
	Sum of Squares and Cross-products	409.727	1060.143	-3315.666	-2389.313	-8803.492	-7774.648	-1776.449
	Covariance	14.129	36.557	-114.333	-82.390	-303.569	-268.091	-61.257
Mother's Education Level	Pearson Correlation	-.140	-.310	.060	.224	.215	.322	.063
	Sig. (2-tailed)	.460	.095	.752	.233	.255	.083	.741
	Sum of Squares and Cross-products	-61.800	-112.000	57.267	203.533	211.264	323.800	58.851
	Covariance	-2.131	-3.862	1.975	7.018	7.285	11.166	2.029
Father's Education Level	Pearson Correlation	-.098	-.205	.032	.299	-.025	.187	-.090
	Sig. (2-tailed)	.606	.278	.865	.109	.894	.323	.636
	Sum of Squares and Cross-products	-38.600	-66.000	27.533	242.067	-22.299	167.600	-75.402
	Covariance	-1.331	-2.276	.949	8.347	-.769	5.779	-2.600

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		Force Concept Inventory Adjusted Score Post-test	Force Concept Inventory Score Change	Mother's Education Level	Father's Education Level
Perception of Science Difficulty Score	Pearson Correlation	-.112	.080	-.140	-.098
	Sig. (2-tailed)	.554	.674	.460	.606
	Sum of Squares and Cross-products	-178.700	409.727	-61.800	-38.600
	Covariance	-6.162	14.129	-2.131	-1.331
Perception of Math Difficulty Score	Pearson Correlation	-.167	.253	-.310	-.205
	Sig. (2-tailed)	.377	.177	.095	.278
	Sum of Squares and Cross-products	-218.000	1060.143	-112.000	-66.000
	Covariance	-7.517	36.557	-3.862	-2.276
Anxiety of Science Score	Pearson Correlation	-.008	-.300	.060	.032
	Sig. (2-tailed)	.967	.107	.752	.865
	Sum of Squares and Cross-products	-27.433	-3315.666	57.267	27.533
	Covariance	-.946	-114.333	1.975	.949
Anxiety in Math Score	Pearson Correlation	-.022	-.227	.224	.299
	Sig. (2-tailed)	.907	.227	.233	.109
	Sum of Squares and Cross-products	-72.617	-2389.313	203.533	242.067
	Covariance	-2.504	-82.390	7.018	8.347
Force Concept Inventory Total Score Pre-test	Pearson Correlation	.499**	-.771**	.215	-.025
	Sig. (2-tailed)	.005	.000	.255	.894
	Sum of Squares and Cross-products	1774.368	-8803.492	211.264	-22.299
	Covariance	61.185	-303.569	7.285	-.769
Force Concept Inventory Adjusted Score Pre-test	Pearson Correlation	.441*	-.667**	.322	.187
	Sig. (2-tailed)	.015	.000	.083	.323
	Sum of Squares and Cross-products	1599.450	-7774.648	323.800	167.600
	Covariance	55.153	-268.091	11.166	5.779

		Force Concept Inventory Adjusted Score Post-test	Force Concept Inventory Score Change	Mother's Education Level	Father's Education Level
Force Concept Inventory Total Score Post-test	Pearson Correlation	.759**	-.164	.063	-.090
	Sig. (2-tailed)	.000	.388	.741	.636
	Sum of Squares and Cross-products	2565.575	-1776.449	58.851	-75.402
	Covariance	88.468	-61.257	2.029	-2.600
Force Concept Inventory Adjusted Score Post-test	Pearson Correlation	1.000	-.101	.100	.060
	Sig. (2-tailed)	.	.594	.598	.753
	Sum of Squares and Cross-products	4009.367	-1305.162	111.467	59.433
	Covariance	138.254	-45.006	3.844	2.049
Force Concept Inventory Score Change	Pearson Correlation	-.101	1.000	-.118	.088
	Sig. (2-tailed)	.594	.	.533	.644
	Sum of Squares and Cross-products	-1305.162	41385.527	-422.375	280.183
	Covariance	-45.006	1427.087	-14.565	9.661
Mother's Education Level	Pearson Correlation	.100	-.118	1.000	.748**
	Sig. (2-tailed)	.598	.533	.	.000
	Sum of Squares and Cross-products	111.467	-422.375	307.867	205.733
	Covariance	3.844	-14.565	10.616	7.094
Father's Education Level	Pearson Correlation	.060	.088	.748**	1.000
	Sig. (2-tailed)	.753	.644	.000	.
	Sum of Squares and Cross-products	59.433	280.183	205.733	245.467
	Covariance	2.049	9.661	7.094	8.464

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Listwise N=30

81 82

Appendix P: Chi-square Analysis of Gender with Force Concept Inventory Scores

Force Concept Inventory Total Score Pre-test * Gender

Crosstab

Count

		Gender		
		Male	Female	Total
Force Concept Inventory Total Score Pre-test	3.45		2	2
	6.90		5	5
	10.34		1	1
	13.79		7	7
	17.24	3	3	6
	20.69	1	6	7
	24.14	1	5	6
	31.03	2	1	3
	34.48		2	2
	41.38	3		3
	55.17	1		1
Total		11	32	43

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.739[a]	10	.012
Likelihood Ratio	25.617	10	.004
Linear-by-Linear Association	12.162	1	.000
N of Valid Cases	43		

a. 20 cells (90.9%) have expected count less than 5. The minimum expected count is .26.

Force Concept Inventory Total Score Post-test * Gender

Crosstab

Count

		Gender		
		Male	Female	Total
Force Concept Inventory Total Score Post-test	10.34		1	1
	13.79		2	2
	17.24	1	1	2
	20.69		3	3
	24.14		5	5
	27.59	1	4	5
	31.03	1	4	5
	34.48		4	4
	37.93	2	2	4
	41.38	1	2	3
	44.83	1	1	2
	58.62	1		1
Total		8	29	37

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.823[a]	11	.377
Likelihood Ratio	13.716	11	.249
Linear-by-Linear Association	4.973	1	.026
N of Valid Cases	37		

a. 24 cells (100.0%) have expected count less than 5. The minimum expected count is .22.

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