EXPLORATORY IDENTIFICATION OF INTRODUCTORY ALGEBRA-BASED PHYSICS SUCCESS FACTORS

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ABSTRACT

The field of physics suffers from low student matriculation through its degree programs as well as being viewed as being abstract, complicated, and incomprehensible by students enrolled in introductory courses. A study was performed on a group of 64 students in an introductory physics I course to determine if algebra skill, scientific reasoning ability, reading/comprehension level, or student attitude were significant predictors of success in the course. The study found that female physics achievement could be predicted by algebra ability, scientific reasoning skills, affinity toward traditional teaching practices, scientific attitude. Male physics achievement was found to depend only on desire for conceptual knowledge and meaningful learning. It was also determined that students with scientific reasoning skills did not prefer the traditional lecture-centered educational environment.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the College of Arts and Sciences, have examined a thesis titled, “Exploratory Identification of Introductory Algebra-Based Physics Success Factors”, presented by Andrew Joseph Gnefkow, candidate for the Master of Science degree, and certify that in their opinion it is worthy of acceptance.

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CHAPTER 1

OVERVIEW

Introduction

The development of general scientific abilities is critical to ensure students of science, technology, engineering, and mathematics will have the tools necessary to undertake open-ended real-world scenarios in their future careers (Iyengar,2008; Zheng, 2008; Bloom, 1956; National Research Council, 1996; National Research Council, 2002; Singer et al, 2005). These abilities are not just important to scientist, technicians, and engineers, but also to everyone employed in the healthcare field as well (Zheng, 2008). Increasing science literacy is beneficial to the general public as of science is also valued outside of this robust group of vocations.

The goal of science education research is often focused on science literacy. Science literacy is a term that designates not only science-related knowledge, but also practices and values that science educators hope students acquire during the process of learning science. The pursuit of scientific knowledge provides a system of testable predictions and explanations about the physical world and presents an avenue for the acquisition of critical thinking and deductive reasoning skills. While these skills clearly have value, imparting these skills to students is a difficult process. Because of this, groups of science educators have begun to examine why students do not learn what teachers try to convey, and why achievement gaps persist.

Physics as a scientific discipline has many hurdles to overcome when attempting to educate students. Even though 64% of the scientific education research is completed in the physics domain (Duit, 2005), physics is still perceived as very abstract, complicated, difficult, counterintuitive, and incomprehensible by students (Parker, Rennie, & Fraser, 1996). This has been attributed to the student's pre-instructional ideas having a harsh contrast to those conclusions to be achieved (Wandersee et al., 1994). Other factors have been proposed that contribute to low student achievement in physics.

The study performed in the scope of this work explored proposed factors that could contribute to student learning in an algebra-based introductory physics course. These factors included those that could be influenced by the administration at the university level as well as those that can be influenced in primary and secondary school.

Traditional Practices

The traditional method of teaching physics involves lectures, in which abstract physical concepts are presented to students with mathematical justification of the equations that accompany those concepts. In addition, introductory courses often incorporate example problems for further clarification of the topics discussed. While all of these would appear to enhance a student's learning experience, research in science education has shown that institutions of formal education do not help most students learn science with adequate understanding (Blank & Langesen, 2001; Schmidt et al., 2001). These publications implicate that science educators make a serious effort to identify and alleviate the problems preventing science learning.

The lecture method is effective for a select group of students. This teaching approach is beneficial for students classified as formal learners. Unfortunately, this group of students only comprises approximately five percent of the students enrolled in algebra based physics courses. The remaining ninety-five percent of students must rely on alternative means to grasp the material presented in lecture. These students can employ rote memorization, working excessive examples, or the consultation of other students in an attempt to understand the material. These other learning methods rely on the expertise of the student or their peers, and they contain the potential for student confusion and failure.

As a result of the widespread use of this teaching method, students are prone to didaskalogenic (intentionally instructive) confusion (Simanek, 2008). This, along with the abstract nature of physics, prevents students from overcoming the misconceptions they possessed prior to taking the course and can lead to additional misconceptions resulting from the course (Glynn, 1991). This type of confusions is typical when unsuitable analogies are utilized during instruction, which is typical for a traditional lecture course (Simanek, 2008). Because of this, many introductory physics courses are not serving their primary function of providing a basic foundation of physics knowledge to the students.

The lack of student understanding has prompted educators to incorporate additional activities into their lectures, in an attempt to enhance student understanding. The most common activities employed in a lecture are demonstrations. They are used to supply additional support of physical concept and provide a means for students to recall a particular idea. However, classroom demonstrations have been shown not to help student understanding and in some cases reinforce the misconceptions the demonstration was intended to alleviate (Roth et al., 1997). The ineffectiveness of demonstrations is explained through the lack of student involvement. Demonstrations are just a visual extension of the lecture centered model. They provide an information presentation method more suited to visual learners, but still appear to lack the engagement needed to ensure student learning. Classroom demonstrations have only been shown to directly influence student motivation (Watson, 2000).

The explanation for the ineffectiveness of demonstrations to increase student understanding has been partially attributed to students' preconceived notion of the physical phenomena being demonstrated (Roth et al., 1997). These students witness the event from a different theoretical perspective than the instructor intended for the demonstration. This leads the students to generate an explanation of the events from an alternant perspective, assigning origins of the observed actions incorrectly. The student confusion has also been linked to an inadequate explanation of the demonstration by the instructor performing it (Ogborn et al., 1996).

The lack of significant learning gains from classroom demonstrations does not mean that they should be disregarded as viable teaching tools. Their implementation needs to be modified in order to increase student learning from the experience. For demonstrations to be effective, the instructor must act as a mediator for student learning, as well as be the interpreter of the physical phenomena being observed (Ogborn et al., 1996). Demonstrations can also take on more student-centered characteristics. Students can be encouraged to predict the outcome of a demonstration, observe the results, and explain what they observed (Gunstone, 1995). Student learning through this process has been shown to be influenced by student's prior beliefs. But instructor guidance through the process has shown to significantly reduce these effects (Gunstone, 1995). Student learning gains have also been improved by the incorporation of computer simulations (Linn, 2003). However, this is not always true (Ruiz-Primo et al., 2011).

Introductory physics courses also contain an experimental or laboratory section, which is used to supplement to lecture. Laboratories are thought to provide an opportunity for students to gain an understanding of the scientific method and how it is employed. It is also assumed that lab work will provide a means for students to examine and resolve common conceptual difficulties from the lecture. This constructivist-informed teaching, which emphasizes hands-on experiences, does not appear to directly improve student understanding of science (Hofstein & Lunetta, 2004). In fact, laboratory work does not positively affect students' knowledge of concepts, cognitive abilities, understanding the nature of science, or attitudes (White, 1996).

Similar to classroom demonstrations, laboratory experiments have the potential to nurture a positive attitude. Many authors also believe that laboratories have an enormous potential for teaching science. The inability to reach this potential is attributed to the intellectual environment provided by the instructor. Science teachers must foster an environment that requires students to make sense of their experiences and explore new connections that will lead to student conceptual understanding

(Bleicher, 1994 and 1996). However, until these changes are made the students' time spent in the laboratory will continue to have minimal, if any, impact on student understanding.

Student-Centered Practices

The lecture-centered model for teaching physics must be improved or replaced if more students are to obtain a satisfactory level of physics knowledge, which is required by their academic area of interest. Even with properly implemented classroom demonstrations and laboratory experiences, a majority of students in physics courses are not showing satisfactory learning gains. This has stimulated research into alternatives to the lecture-centered model of teaching introductory physics courses.

One of the changes that have yielded a significant improvement in student learning is a change to a student-centered (or cooperative) teaching style (Lazarowitz & Hertz-Lazarowitz, 1998). Student-centered learning, or cooperative learning, provides opportunities for instructors to engage students in interactive academic activities. Students, on average, in a cooperative learning environment have higher cognitive achievement, more positive attitude, greater self-esteem, more engagement on tasks, increased motivation and enjoyment (Fraser, 1998), and higher level of thinking (Harskamp et al., 2008). This increased understanding, gained through cooperative learning is reflected in students' examination scores as well (Sharma et al., 2005). While these results are promising, there are several barriers to the implementation of cooperative learning in the university setting. These are both curricular and financial.

Cooperative learning is a relatively new approach to teaching science, and faces several challenges to its wide spread implementation. First, this educational approach must be able to address student learning along multiple dimensions of the cognitive, affective, and social domains of learning. Second, the instructors of these classes must be cognizant of the sociocultural peer effects due to ability, gender, and cultural differences (Windschitl, 1998). The former must be addressed by additional research into each of the learning domains. The latter can be accomplished through its incorporation in teacher education programs for both pre-service and in-service teachers.

The financial requirements to create a cooperative learning environment at the collegiate level also provide a significant hurdle to its implementation. In a typical lecture-centered introductory physics course, there are one hundred students being taught by one professor. The average salary of a university professor is $60,000 plus benefits. This same course would require ten instructors, if it were to be operated as a student-centered learning environment. This has now increased the cost of operation of one introductory physics course to $540,000. This cost could be lowered by employing graduate teaching assistants, trained in cooperative learning education, as additional instructors. The cost of a graduate teaching assistant, including salary and fee remissions, is approximately $40,000, a year. Using graduate teaching assistants would increase the cost of one introductory physics course by $180,000. To keep the instructional cost to a minimum, a major renovation of a preexisting lecture hall would need to be completed to create a classroom suited to cooperative learning. The minimal cost of the renovation of a one hundred seat lecture hall would be $400,000 and such a hall would require weekly full time use. As such, educators speculate that changing to the student-centered learning environment would be a costly endeavor.

Attitudes Toward Science

The learning environment is not the only factor that has been shown to affect student learning. Two areas that have been researched are attitudinal and motivational constructs. The term construct refers to a hypothesized psychological function and can infer or account for science thinking, emotions, and actions (Snow, Corno, & Jackson, 1996). Effective science instruction can improve attitudes toward science and heighten the motivation to learn science. Instructors attempt to achieve these through hands-on activities, laboratory work, and inquiry-oriented lessons.

Attitude constructs have been researched for over 100 years, and in that time many measurement tools have been created to gauge the relationship of student attitudes with other variables of interest. Attitude, within education research, is defined as "a general and enduring positive or negative feeling about some person, object, or issue" (Petty & Cacioppo, 1981). Despite a great deal of research, it is unclear what the true effects of a student attitude are on learning. Some studies found favorable effects of activity-oriented instruction on attitudes and others did not, leading to a decline in researcher's interests in the mid-nineties (Simpson et al., 1994). These issues have been somewhat resolved by the separation of attitude and beliefs, where attitudes are associated with affects and beliefs with cognition. A further relationship was found that personal beliefs are the determinants of student attitudes. The research on student attitudes, and associated variables, has become convoluted with disagreements over definitions of the characteristics being examined. This has made attitude research more difficult to conduct and made any results more difficult to interpret.

While student attitudes toward science have been found to have a strong effect on achievement in countries outside of the United States (Webster & Fisher, 2000), attitudes were not found to predict physics achievement (Willson, Ackerman, & Malave, 2000), and more generally not be directly related to science achievement among American students (Singh, Granville, & Dika, 2002). The weak relationships shown may be due to the extremely narrow definitions of both attitude and achievement used in studies of this nature (Rennie & Punch, 1991). However, this absent relationship between achievement and attitude (in Americans) has been reported for some time (Fraser, 1982). Student attitudes have also been shown to influence their pursuit of careers in science (Robertson, 2000).

In addition to attitude constructs, motivation has been researched to determine its influence on science learning. Student motivation has not been researched as heavily as student attitudes, but it is believed that attitudes influence motivation which influence learning. Student motivation is defined as an internal state that arouses, directs, and sustains students' behavior. Motivation research attempts to explain why students strive for certain goals when learning science, how intensely they strive, how long they strive, and what feelings and emotions characterize them in this process. Student motivation research has formed correlations with arousal and anxiety, interest and curiosity, intrinsic and extrinsic motivation, self-determination, goal-directed behavior, selfregulation, and instructor expectations. However, none of these has provided a clear correlation with achievement or student understanding.

Scientific Reasoning

Another factor that has been related to student understanding is scientific reasoning ability. Scientific reasoning is utilizing critical thinking skills for evaluating scientific information, and has been positively correlated with physics achievement. Research concerning student scientific reasoning has focused on the area of active reasoning, which is engaged when a student is attempting to solve problems in the classroom. There have been different methods for engaging active reasoning. Some students generate analogies (Harrison & de Jong, 2005; Cosgrove, 1995), while others reason through classroom discussion (Hammer, 1995; Schultz & Clement, 1994; Harrison & Treagust, 2000). It is clear that reasoning abilities are crucial, if students are going to apply the basic scientific principles learned in lecture to solve real-world problems.

Mathematics Abilities

Mathematics in an integral part of physics, and is required if one is to obtain any quantitative value from a physical situation. Because of this, algebra skill has been examined as a possible predictor of physics course success. These studies found that, along with critical thinking skill, algebra skill was a predictor of course performance, but only for female students (McCammon et al., 1988). Possible explanations for this relationship are females' desire to be viewed as more conforming students (Anastasi, 1982), and the gender's perception of their aptitude in the field of physics (Griffith, 1985). The results of these mathematics studies yielded positive results, but also suggested that success factors for students may differ depending of the student's gender.

Reading/Comprehension Ability

Reading comprehension is defined as a level of understanding of a piece of writing, and proficiency in this area depends on an individual's ability to recognize words quickly and effortlessly (Adams, 1994). Familiarity with the terms used in a piece of text allows for the maximal amount of a student's processing capacity to be used to comprehend it. Physics involves an interpretation of facts often presented in a word problem, so one could infer that there would be a connection between a student's understanding and their achievement. The United States National Reading Panel concluded that the critical skills needed for effective reading comprehension are vocabulary knowledge, reading comprehension based on reading strategies, and practices (National Reading Panel, 2000). If there is a connection between reading comprehension and physics achievement, then these factors should be examined further.

Gender

Gender has also been an intense area of research, within science education. Worldwide, there is a disproportionate representation of the genders in science, mathematics, engineering, and technology vocations (New Zealand Bureau of Statistics, 2004; Australian Bureau of Statistics, 2004; Statistics Canada, 2004, Mervis, 2003). Additionally, female students that have enrolled in physics courses have lower self-efficacy, performance goals, and understanding the males (Cavallo et al, 2004). The areas of interest related to gender research are why female students do not participate in science and why the female students that do participate in science do not perform as well as their male counterparts, along with possible solutions for these problems.

The factors that influence students' rate of participation in science has changed drastically over the past fifty years. Historically, researchers believed that the differences between male and female students successful participation in science was due to physiological differences between the sexes that relate to the processing of information (Field & Copley, 1969). These studies also concluded that the slower development of formal operations by female students was the reason for their lower achievement scores. Later studies attributed the gender gap to social/cultural differences, and to a lesser extent school experiences (Kelly, 1978). It was also found that the link between liking science and achievement was stronger for male students than for female students (Kelly, 1978).

More recently, research into the gender gap found considerable evidence attributing performance differences in mathematics, spatial ability, and differential experiences (activities outside of school) as the source for the difference in gender performance (Kahle & Meece, 1994). However, these differences in mathematics and spatial abilities were not large enough to account for the total difference in science achievement (Kahle & Meece, 1994). Race, socioeconomic status, and student learning strategies have also been related to gender differences in participation, attitudes, achievement (Kenway & Gough, 1998). The completion of a physics course in high school has been shown to be positively linked to conceptual understand, but even within this group of students, the gender gap persists (Antimirova et al., 2009). Differences in achievement can be attributed to prior physics and mathematics performance, and the student's incoming attitude and beliefs (Kost et al., 2009).

The identification of race, socioeconomic status, and learning strategy are valuable to the identification of the cause of the gender gap, but this information does not provide a path for its reduction or alleviation. Science education researchers have shifted their research efforts to identifying factors contributing to the gender gap that can be addressed through changes by school administrators or within the classroom itself. Research into this area discovered methods for the reduction of the gender gap.

One of the factors identified as a contributor to the gender gap is stereotype threat, which may alleviate through self-affirmation (Cohen et al., 2006). The gender gap was reduced for students who completed two affirmation exercises at the beginning of the semester (Kost-Smith et al., 2010). Reduction of the gender gap has also been attempted through the use of interactive engagement techniques (Lorenzo et al., 2006). However, when the interactive learning environment was applied in a different university setting, the gender gap was not eliminated or even reduced (Pollock et al., 2007). Pollock's study showed that interactive learning techniques did provide an atmosphere that increased learning for all students, but the gender gap was actually increased. A great deal of work has gone into identifying the cause of the gender gap, but equalizing male and female performance will require more research.

CHAPTER 2

METHODOLOGY

Introduction

The participants of this study were enrolled in a general physics course at the University of Missouri-Kansas City. This course was operated in a traditional, lecture-centered, manner. Two different groups of tests/survey were completed by students who chose to participate in the study. The first set was collected in the first week of the semester and the second was collected in the last month of the semester. The first set of tests/surveys assessed the students' scientific reasoning abilities, algebra skills, demographic information, and their previous knowledge of mechanics. The second set of tests/surveys assessed the students' reading-comprehension skills, study habits, attitude/expectations, and the same set of mechanics questions given at the beginning of the semester.

The tests/surveys were posted on a blackboard organization site. The organization website has secure socket layers throughout the site to protect transmitted information. Consenting students were granted access to the site and allowed a month to complete each group of tests/surveys. The tests, meant to assess a particular skill, were given in a multiple choice format with each set of answered being randomized for each participant. The attitude and habits surveys were answers on a Likert scale. The Mechanics Baseline Initial, Algebra Test, Demographic Information survey, and the

Lawson Classroom Test of Scientific Reasoning were given at the beginning of the semester. At the end of the semester, the students completed the Mechanics Baseline Final, Reading assessment, the Maryland Physics Expectation survey (MPEX), and Study Habits survey.

Tests and Surveys

Each participant's basic demographic information was provided through the use of the National Science Foundation's Demographic Information Survey. The survey asks the participants to indicate their gender, citizenship, ethnicity, race, and if they have disability status. This data was collected at the beginning of the semester through the blackboard survey site.

Lawson's Classroom Test of Scientific Reasoning rev. Ed (Lawson) is an assessment of formal-level reasoning (Lawson, 1978; Lawson, 2000). The Lawson is comprised of a set of twenty-four questions that examine proportional reasoning, deductive and inductive reasoning, control of variables, probability reasoning, correlation reasoning, and hypothesis evaluation (Bao et al., 2009). Each of these is crucial for achievement in the sciences.

The Mechanics Baseline Test was used as a means to assess student learning gains over the semester. The test was developed to assess basic mechanics skills (Hestenes & Wells, 1992). The test serves as a qualitative assessment of student's knowledge in the areas of kinematics, Newton's laws, energy, momentum, and the specific forces of gravity and friction. It supplies distracters that target typical misunderstanding, not typical mistakes due to carelessness, justifying its use to gauge student learning gains (Hestenes & Wells, 1992). Reliability studies of the Mechanics Baseline Test have found it to be a reliable tool for gauging a student's knowledge of introductory physics mechanics.

The version of the Mechanics Baseline Test that was administered to the participants of this study was reduced in length and slightly modified from the original version of the test. The study's version contained nine questions, seven questions from the Mechanics Baseline test and two questions created as follow-up questions to one of the original seven questions. The three sets of three each target a different mechanics concept. The first three questions assess the student's understanding of a graphical representation of kinematics. The second three questions assess a student's understanding of work and energy. The third set of three questions evaluates the student's knowledge of Newton's second law and free-body diagrams.

The Algebra Ability Assessment was created to evaluate the students' proficiency at basic algebra. The test is comprised of nine questions that evaluate three different algebra skill areas. The general skills that were tested were taken from the mathematics placement test administered by the University of Missouri-Kansas City Mathematics and Statistics department. The three areas examined were single variable algebraic equations, quadratic equations, and systems of equations. In addition to these three skills tested, one question from each set was presented as a word problem. This was done to ascertain any correlation between reading skill and mathematics ability.

The reading-comprehension test was a six paragraph passage followed by eight questions asking the students to analyze and infer facts about the passage. The passage was taken from a set of previously used verbal reasoning sections for the Medical College Admissions Test. The Medical College Admissions Test is designed to assess a student's problem solving ability, critical thinking skills, and knowledge of science concepts and principles that a collegiate student should possess. The verbal reasoning section tests student understanding of what the author of a passage is thinking or doing.

The Maryland Physics Expectations survey is used to assess student attitudes, beliefs, and expectations which have an effect on what they learn in an introductory physics course (Redish et al., 1998). Students are asked to agree or disagree with a set of statements about how they perceive physics and how they think they work in their course. Their responses are scored on a Lilert scale. The student responses are compared to answer given by experts, and students who respond similarly are considered effective scientists and life-long learners.

Linear Regression Analysis

Regression analysis is a statistical technique that accounts for or predicts the variance in an interval dependent variable. It is based on linear combinations of intervals, dichotomous, or dummy independent variables. Performing a multiple regression can establish that a set of independent variables can explain a proportion of the variance in a dependent variable at a significant level as well as determine the relative predictive importance of the independent variables. These two properties are determined by a significance test of R^2 and comparing beta weights, respectively. The general expression for a multiple regression is stated in equation 1. Each b_i is a regression coefficient representing the amount of change in the dependent variable y when the

$$y = b_1x_1 + b_2x_2 + \ldots + b_nx_n + c$$

corresponding independent variable, x_i, changes by one unit. The c is the y-intercept of the multiple regression function. The c-value represents the amount of the dependent variable when all of the independent variables are zero.

The results of a linear regression performed in SPSS are given in tables. Each of the proposed independent variables is given unstandardized and standardized coefficients, as well as a t-value and significance value. The value of the standardized coefficient, Beta, is the amount of the variance that can be associated with the corresponding independent variable. This value can also indicate a positive or negative correlation, based on the sign of the beta value. The significance value is used to determine if the independent variable is a significant predictor of the dependent variable. In order for an independent variable to be considered significant, the significance value determined must be less than or equal to 0.01. Weak correlation corresponds to a value of 0.015 or below.

Reliability Analysis

The Cronbach's alpha is used to measure the internal consistency or reliability of a test. Created by Lee Cronbach in 1951, the alpha is defined as

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} \sigma_{Y_i}^2}{\sigma_X^2}\right)$$

where K is the number of components, σ_X^2 is the variance of the observed total test scores for the current sample of students, and $\sigma_{Y_i}^2$ is the variance of the component for the i^{th} student. The value of alpha will increase as the amount of intercorrelation between each test question increases. This characteristic allows for a measure of internal consistency of the test scores.

Factor Analysis: Varimax Rotation

Factor analysis is used to describe variability in a set of observed variables in terms of a lower number of unobserved variables. Through factor analysis, it is possible to determine that the variability in a small set of variables can be represented by the variability in a single variable. This exploratory factor analysis creates a new smaller set of variables from the original large set of variables, which can simplify further analysis.

Completing a factor analysis requires assumptions pertaining to the mean, variance, and correlation of the data set. For factor analysis, the specific factors or errors are assumed to have a mean of zero. The justification for this is the assumption of the errors being random errors. Also the unobserved variables, called common factors, will have a mean of zero. The common factors are also assumed to have a variance of 1. Additionally, the specific factors are assumed to have some variance. Lastly, the common factors are assumed to be uncorrelated with one another, the specific factors are assumed to be uncorrelated, and the specific factors are assumed to be uncorrelated with the common factor.

Once the factor or component matrix has been constructed, it undergoes a rotation. This rotation is completed to make the component groupings more understandable for interpretation. A varimax rotation is one such method. The varimax rotation is an orthogonal rotation of the component axes, done to differentiate each component from the original variable. This is accomplished by maximizing the variance of the square loadings of a component in the component matrix.

CHAPTER 3

RESULTS

Linear Regression Analysis

The Statistical Package for the Social Science (SPSS) software was used to perform a linear regression analysis on the student population, with the Mechanics Baseline Final score as the dependent variable. In this analysis the student's score on the Algebra test, Lawson Test, Reading Test, and the Mechanics Baseline Initial Test were used as possible independent variables. The results are found in Table 1.

Table 1. Linear Regression with the Mechanics Baseline Final Score as the Dependent Variable

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.262	1.712		-.153	.879
	AlgebraScore	.168	.273	.097	.614	.544
	LawsonScore	.022	.057	.053	.380	.707
	ReadingScore	.125	.127	.119	.982	.334
	MechBaselineInitial	.783	.164	.685	4.762	.000

Further analysis of this data indentified Question 3 in the Mechanics Baseline Test to be unreliable. This question was removed, and an additional linear regression analysis was performed. The results are found inTable 2.

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Table 2. Linear Regression with the Corrected Mechanics Baseline Final Score as the Dependent Variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.874	.916		-.954	.344
	LawsonScore	-.027	.040	-.079	-.683	.497
	ReadingScore	-.027	.096	-.027	-.279	.781
	MBLIcorrected	.697	.129	.567	5.389	.000
	AlgebraScore	.382	.157	.290	2.440	.018

The linear regression results shown in Table 2 shows that the Mechanics Baseline Initial score was a significant predictor of performance on the Mechanics Baseline Final Test. Since these two tests are identical, this supports that this is a valid tool for assessing mechanics understanding.

Linear regressions were performed controlling for gender. The results for male students are found in Table 3 and the results for female students are found in Table 4.

Table 3. Linear Regression with the Corrected Mechanics Baseline Final Score as the Dependent Variable for Male Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.466	1.668		.279	.782
	LawsonScore	.022	.059	.055	.382	.706
	ReadingScore	.042	.145	.036	.288	.776
	MBLIcorrected	.860	.175	.717	4.914	.000
	AlgebraScore	.070	.279	.041	.250	.804

The results of the linear regression for male students showed the Mechanics Baseline Initial score as the only significant variable depending on the Mechanics Baseline Final score.

Table 4. Linear Regression with the Corrected Mechanics Baseline Final Score as the Dependent Variable for Female Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-1.253	.709		-1.768	.089
	LawsonScore	-.207	.042	-.743	-4.885	.000
	ReadingScore	.120	.086	.165	1.391	.176
	MBLIcorrected	.646	.129	.616	5.002	.000
	AlgebraScore	.646	.123	.721	5.266	.000

The linear regression performed for female students, with the Mechanics Baseline Final score as the dependent variable, found three significant variables. Both the Mechanics Baseline Initial score and the Algebra score were found to be positively correlated with the Mechanics Baseline Final score. The Lawson score was determined to also be a significant variable, but it is negatively correlated with the Mechanics Baseline Final score.

A linear regression analysis was performed with the student's score on the Algebra Test as the dependent variable. The student's Lawson score, Reading score and Mechanics Baseline Initial and Final score were used as possible independent variables. The results are found in Table 5.

Table 5. Linear Regression with the Algebra Score as the Dependent Variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.469	.443		10.086	.000
	LawsonScore	.114	.028	.434	4.020	.000
	ReadingScore	.064	.076	.085	.852	.398
	MBLIcorrected	.058	.125	.062	.461	.647
	MBLFcorrected	.240	.098	.316	2.440	.018

The results of the linear regression found a significant, positive correlation between the student's score on the Lawson survey and the Algebra Test. A subsequent linear regression was performed controlling for gender. The results for male students are found in Table 6, and female students in Table 7.

Table 6. Linear Regression with the Algebra Score as the Dependent Variable for Male Students

Coefficients[a,b]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	4.977	.628		7.922	.000
	LawsonScore	.092	.036	.385	2.558	.016
	ReadingScore	-.006	.099	-.009	-.062	.951
	MBLIcorrected	.283	.153	.404	1.855	.074
	MBLFcorrected	.032	.128	.055	.250	.804

The results of the linear regression for male students found that none of the proposed variables were significant predictors of male student performance on the Algebra Test. There was almost a weak correlation between the Lawson score and Algebra score, but not enough for consideration.

Table 7. Linear Regression with the Algebra Score as the Dependent Variable for Female Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	3.170	.555		5.708	.000
	LawsonScore	.245	.044	.789	5.562	.000
	ReadingScore	-.065	.098	-.081	-.666	.511
	MBLIcorrected	-.453	.180	-.388	-2.513	.019
	MBLFcorrected	.798	.152	.716	5.266	.000

The linear regression for female students found a positive, significant correlation between female students' Lawson score and Mechanics Baseline Final Score with their Algebra score.

A linear regression analysis was performed with the Reading score as the dependent variable. The Lawson score, Mechanics Baseline Initial and Final score, and Algebra score were used as possible independent variables. The results are found in Table 8.

Table 8. Linear Regression with the Reading Score as the Dependent Variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.656	1.248		.526	.601
	LawsonScore	.067	.054	.194	1.241	.220
	MBLIcorrected	-.072	.214	-.058	-.336	.738
	MBLFcorrected	-.049	.176	-.049	-.279	.781
	AlgebraScore	.189	.221	.143	.852	.398

The results of the linear regressions analysis did not show any significant correlation between the students' Reading score and any of the proposed independent variables. These results were also true for linear regressions performed controlling for gender.

Reliability Analysis

A Cronbach's Alpha reliability test was performed on the student responses to the Algebra test. The results are found in Table 9.

Table 9. Reliability Statistics for the Algebra Test

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.268	.224	8

The SPSS software removed the second question from the analysis because every student answered the question correctly. The value for the Cronbach’s Alpha is low for reliability standards. An individual item analysis is found in Table 10.

Table 10. Algebra Test Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Algebra1	5.4219	1.645	-.082	.145	.299
Algebra3	5.5938	1.324	.161	.293	.207
Algebra4	5.5469	1.331	.206	.134	.185
Algebra5	5.6406	1.408	.038	.142	.286
Algebra6	5.7031	1.323	.090	.165	.253
Algebra7	5.6094	1.194	.297	.152	.111
Algebra8	5.6563	1.340	.097	.179	.247
Algebra9	5.5625	1.520	-.028	.211	.315

The results in Table 10 show that there were no systematic errors in the Algebra Skills Test. The results also show that the questions used in the Algebra Skills Test all have approximately the same reliability.

A Cronbach’s Alpha reliability analysis was performed on the results of the Reading-comprehension study. The results are found in Table 11.

Table 11. Reliability Statistics for the Reading Test

Cronbach's Alpha	N of Items
.483	8

The results of the Cronbach's Alpha analysis showed that the Reading test is a reliable analytical tool. An individual item analysis was performed to evaluate each question used in the test. The results are found in Table 12.

Table 12. Reading Test Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Reading1	2.5938	2.626	.226	.459
Reading2	2.4531	2.442	.203	.456
Reading3	2.2031	2.164	.303	.411
Reading4	2.2031	2.418	.124	.491
Reading5	2.2031	2.164	.303	.411
Reading6	2.4063	2.563	.080	.501
Reading7	2.2813	2.269	.243	.439
Reading8	2.2500	2.190	.292	.417

The results of the itemized analysis of the Reading Test found no systematic errors in the Reading test, and determined that it was a valid tool for assessing the students' reading abilities.

A Cronbach's Alpha reliability analysis was performed on the responses to the Lawson survey. The results are found in Table 13.

Table 13. Reliability Statistics for the Lawson Survey

Cronbach's Alpha	N of Items
.830	24

The results of the Cronbach's Alpha analysis show the Lawson survey is reliable analytic tool for gauging the student's scientific reasoning abilities. An individual item analysis was performed; the results are found in Table 14.

Table 14. Lawson Survey Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
LAWSON1	14.0156	23.508	.189	.830
LAWSON2	13.9844	23.349	.374	.827
LAWSON3	14.2656	23.024	.172	.833
LAWSON4	14.2969	22.339	.319	.827
LAWSON5	14.3906	21.035	.595	.814
LAWSON6	14.4063	21.229	.548	.816
LAWSON7	14.4531	22.347	.296	.828
LAWSON8	14.4375	22.345	.297	.828
LAWSON9	14.1875	23.647	.044	.837
LAWSON10	14.2188	22.523	.306	.827
LAWSON11	14.4688	22.189	.331	.826
LAWSON12	14.6250	23.508	.061	.837
LAWSON13	14.7500	24.159	-.078	.840
LAWSON14	14.4375	22.472	.270	.829
LAWSON15	14.1875	21.234	.660	.813
LAWSON16	14.0781	22.168	.552	.819
LAWSON17	14.1719	21.097	.717	.811
LAWSON18	14.2344	21.325	.593	.815
LAWSON19	14.2344	21.071	.658	.812
LAWSON20	14.2656	21.658	.491	.819
LAWSON21	14.5625	21.234	.560	.816
LAWSON22	14.4688	21.396	.507	.818
LAWSON23	14.4688	21.555	.472	.820
LAWSON24	14.3125	22.790	.214	.831

The itemized Cronbach’s Alpha analysis determined that the Lawson Test was comprised of valid questions and contained no questions indicating a systematic error.

A Cronbach's Alpha reliability analysis was performed on the Mechanics Baseline Initial and Final tests. The results for the Mechanics Baseline Initial Test are found in Table 15.

Table 15. Reliability Statistics for the Corrected Mechanics Baseline Initial Test

Cronbach's Alpha	N of Items
.172	8

The Chonbach's Alpha value, found in Table 15, show a low reliability for the Mechanics Baseline test. An individual item analysis is found in Table 16.

Table 16. Corrected Mechanics Baseline Initial Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
MBLI1	2.6563	1.499	.185	.058
MBLI2	2.5938	1.483	.182	.057
MBLI3	2.7656	1.706	.049	.162
MBLI5	2.4219	1.422	.241	.007
MBLI6	2.3125	1.901	-.127	.279
MBLI7	2.7656	1.738	.021	.181
MBLI8	2.8594	1.837	-.019	.198
MBLI9	2.7344	1.785	-.032	.217

A Cronbach's Alpha analysis was also performed on the student results of the Mechanics Baseline Final Test. The results of this analysis are found in Table 17.

Table 17. Reliability Statistics for the Corrected Mechanics Baseline Final Test

Cronbach's Alpha	N of Items
.436	8

The results of the Cronbach's Alpha analysis show a much increased reliability of the Mechanics Baseline Final Test, compared to the pretest. This does raise some concern since they are the same test. An individual item analysis was performed for the Mechanics Baseline Final Test, with the results found in Table 18.

Table 18. Corrected Mechanics Baseline Final Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
MBLF1	2.8125	1.996	.259	.369
MBLF2	3.0313	1.872	.401	.299
MBLF3	3.1094	2.448	-.017	.487
MBLF5	2.5938	2.213	.173	.411
MBLF6	2.6719	2.160	.172	.411
MBLF7	3.1250	2.333	.076	.449
MBLF8	3.2188	2.078	.409	.328
MBLF9	2.9531	2.204	.113	.441

The results of the individual item analysis show that there were no systematic errors in the test and that all of the questions used in the Mechanics Baseline Test had approximately the same reliability.

Creation of the Attitude Variable

A Varimax rotation analysis was completed on the student responses to the Attitude survey. The results of the analysis were arranged into an ordered rotation matrix, found in Table 19.

Table 19. Ordered Rotated Component Matrix of MPEX Statements

	Component									
	1	2	3	4	5	6	7	8	9	10
Attitude25	.872	.145	.057	-.154	-.075	-.001	-.019	.003	.066	.125
Attitude31	.783	.005	.076	-.128	-.104	.246	-.180	.103	.137	-.286
Attitude16cor	.729	.011	-.414	.071	.061	.135	-.141	-.218	.118	.032
Attitude27cor	.695	.009	.071	.502	.049	-.093	.228	.119	.012	.140
Attitude10cor	.608	.200	.098	.036	.559	.244	-.214	.140	.130	.130
Attitude28cor	-.070	.857	.056	.187	.060	-.002	-.101	-.161	.101	-.128
Attitude2cor	.180	.766	.082	.131	.143	.028	-.210	-.234	.223	.159
Attitude26	.328	.711	-.133	.158	-.284	.039	.130	-.122	.268	-.232
Attitude20cor	.063	.666	.074	.003	-.096	.009	.217	.427	.002	.168
Attitude14cor	.093	.187	.851	-.088	-.059	-.067	.145	-.040	-.064	.082
Attitude15cor	.163	.002	.594	.329	.321	.154	-.124	.349	.001	.293
Attitude13cor	-.185	.236	.544	-.147	-.133	.060	.559	.292	.037	.113
Attitude22cor	-.072	.192	.091	.868	.089	.055	.004	-.084	-.184	-.082
Attitude11	-.193	.151	-.276	.772	-.145	.210	-.087	.264	.077	-.081
Attitude17cor	.453	-.093	.385	.588	.200	.131	-.022	-.200	-.096	.077
Attitude8cor	.388	.320	-.143	.504	.343	.289	.237	.295	-.184	-.138
Attitude27cor	.695	.009	.071	.502	.049	-.093	.228	.119	.012	.140
Attitude34	.035	-.011	.133	.070	.823	-.054	.185	.118	-.079	-.012
Attitude3	-.186	-.048	-.385	-.016	.658	-.107	.012	-.443	-.017	-.069
Attitude10cor	.608	.200	.098	.036	.559	.244	-.214	.140	.130	.130
Attitude21cor	-.078	.069	-.075	.248	.302	.789	-.063	.301	-.118	-.229
Attitude4cor	.242	-.150	.075	.242	.107	.714	.169	-.160	.052	-.201
Attitude19cor	.066	.332	-.088	-.118	-.323	.650	.294	.113	.149	.098
Attitude23cor	-.096	-.109	.051	-.024	.201	.026	.911	-.003	-.003	.099
Attitude29cor	-.093	-.004	.328	.175	-.006	.363	.609	.323	-.053	.260
Attitude13cor	-.185	.236	.544	-.147	-.133	.060	.559	.292	.037	.113
Attitude30	.146	.218	-.091	-.207	.011	.067	.035	.020	.864	-.036
Attitude24cor	.255	.331	-.121	.029	-.132	.166	-.058	.306	.670	-.335
Attitude32	.095	-.140	.209	-.125	.177	-.146	.360	.037	.035	.781
Attitude18	.046	.229	.266	-.012	-.352	-.153	-.006	.027	-.259	.763

The completion of the varimax rotation created a new set of variables, each comprised of a set of statements from the MPEX survey. The statements that correspond with each variable are found in Table 20. The questions associated with a negative attitude toward science are indicated by a negative sign (-) in front of their statement.

Table 20. MPEX Statements that Comprise the Attitude Variables found in the Varimax Rotation

Variable	Statements that Comprise the Attitude Variable
Variable 1	Learning physics helps me understand situations in my everyday life. I use the mistakes I make on homework and on exam problems as clues to what I need to do to understand the material better. (-) The derivations or proofs of equations in class or in the text has little to do with solving problems or with the skills I need to succeed in this course. (-) Understanding physics basically means being able to recall something you've read or been shown. (-) Physical laws have little relation to what I experience in the real world.
Variable 2	(-) Spending a lot of time (half an hour) working on a problem is a waste of time. If I don't make progress quickly, I'd be better off asking someone (-) All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in problems. When I solve most exam or homework problems, I explicitly think about the concepts that underlie the problem. (-) If I don't understand a particular equation needed for a problem in an exam there's nothing much I can do (legally!) to come up with it.
Variable 3	(-) Learning physics is a matter of acquiring knowledge that is specifically located in the laws, principles, and equations given in class and/or in the textbook. (-) In doing a physics problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation. (-) My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it.

Variable 4	(-) Physics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for what I have to do in this course. A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough. (-) Only very few specially qualified people are capable of really understanding physics. (-) In this course, I do not expect to understand equations in an intuitive sense; they must just be taken as givens. (-) Understanding physics basically means being able to recall something you've read or been shown.
Variable 5	Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and/or in the text. I go over my class notes carefully to prepare for tests in this course. (-) Physical laws have little relation to what I experience in the real world.
Variable 6	(-) Problem solving in physics basically means matching problems with facts or equations and then substituting values to get a number. (-) The most crucial thing in solving a physics problem is finding the right equation to use. (-) If I came up with two different approaches to a problem and they gave different answers, I would not worry about it; I would just choose the answer that seemed most reasonable. (Assuming the answer is not in the back of the book.)

From the statements in Table 20, each attitude variable can be assigned a descriptive label. The labels for each attitude variable can be found in Table 21.

Table 21. Attitude Factors

Component Number	Component Group Name	Percentage of Variance
1	Value Physics Knowledge	11.77%
2	Prefers Traditional Practices	10.13%
3	Desire for Conceptual Knowledge	9.98%
4	Scientific Attitude	8.77%
5	Meaningful Learners	8.60%
6	Problem Solving	8.31%

Linear Regression Analysis with the Attitude Variables

A linear regression analysis was performed on the set of attitude variables determined by the Varimax rotation. This analysis was performed with the Mechanics Baseline Test score as the dependent variable. The results are found in Table 22. Additional linear regressions were performed, controlling for gender, males students found in Table 23 and female student in Table 24

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Table 22. Linear Regression with the Corrected Mechanics Baseline Final Score as the Dependent Variable

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-1.832	1.177		-1.556	.125
	MBLIcorrected	.866	.114	.704	7.602	.000
	Value Physics Knowledge	-.431	.279	-.164	-1.547	.128
	Prefers Traditional Practices	.105	.215	.047	.489	.627
	Desire for Conceptual Knowledge	.549	.195	.256	2.815	.007
	Scientific Attitude	-.056	.219	-.027	-.254	.800
	Meaningful Learners	.696	.275	.251	2.533	.014
	Problem Solving	.097	.205	.046	.476	.636

The linear regression analysis, with the Mechanics Baseline Final Score as the dependent variable, showed a significant correlation between the Mechanics Baseline Initial and Final scores. There is also a slightly significant correlation between the Mechanics Baseline Final score and the Desire for Conceptual Knowledge attitude variable. Further regression analysis was performed with the Mechanics Baseline Final score as the dependent variable, controlling for gender. The results for male students are found in Table 23, the results for female student s are found in Table 24.

Table 23. Linear Regression with the Corrected Mechanics Baseline Final Score as the Dependent Variable for Male Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.017	1.358		-1.486	.150
	MBLIcorrected	.925	.111	.772	8.353	.000
	Value Physics Knowledge	.713	.431	.176	1.654	.111
	Prefers Traditional Practices	-.209	.567	-.068	-.369	.716
	Desire for Conceptual Knowledge	.708	.198	.369	3.578	.001
	Scientific Attitude	-.770	.436	-.313	-1.767	.089
	Meaningful Learners	.758	.286	.288	2.652	.014
	Problem Solving	.138	.205	.067	.676	.505

The results of the linear regression analysis for male students found a positive, significant correlation between both the Mechanics Baseline Initial score and the Desire for Conceptual Knowledge attitude variable with the Mechanics Baseline Final score.

Table 24. Linear Regression with the Corrected Mechanics Baseline Final Score as the Dependent Variable for Female Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.135	1.728		-1.235	.229
	MBLIcorrected	.776	.202	.740	3.835	.001
	Value Physics Knowledge	-1.203	.673	-.504	-1.788	.087
	Prefers Traditional Practices	.691	.262	.467	2.640	.015
	Desire for Conceptual Knowledge	.111	.389	.050	.284	.779
	Scientific Attitude	.741	.278	.517	2.667	.014
	Meaningful Learners	.784	.528	.326	1.484	.151
	Problem Solving	-.006	.343	-.004	-.019	.985

The results of the linear regression analysis for the female students only found a positive, significant correlation between the Mechanics Baseline Initial and Final score. In contrast to the male students, having a desire for conceptual knowledge and being a meaningful learner were not found to be a significant predictor of physics achievement.

A linear regression analysis was performed with the attitude variables as independent variables and Algebra score as the dependent variable, controlling for gender. The results for male and female students are found in Tables 25 and 26, respectively.

Table 25. Linear Regression with the Algebra Score as the Dependent Variable for Male Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	5.217	1.618		3.224	.003
	Value Physics Knowledge	-.123	.513	-.052	-.239	.813
	Prefers Traditional Practices	.071	.678	.039	.104	.918
	Desire for Conceptual Knowledge	.107	.234	.095	.457	.652
	Scientific Attitude	.374	.522	.260	.715	.481
	Meaningful Learners	.236	.343	.153	.687	.498
	Problem Solving	.160	.245	.133	.654	.519

The linear regression analysis for male students showed no significant correlation between their Algebra score and any of the attitude factors.

Table 26. Linear Regression with the Algebra Score as the Dependent Variable for Female Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	10.890	1.485		7.333	.000
	Value Physics Knowledge	-.796	.699	-.299	-1.139	.266
	Prefers Traditional Practices	-.117	.299	-.071	-.392	.699
	Desire for Conceptual Knowledge	-1.047	.433	-.426	-2.417	.024
	Scientific Attitude	.285	.331	.178	.858	.399
	Meaningful Learners	-.784	.524	-.293	-1.496	.148
	Problem Solving	.799	.407	.404	1.960	.062

The linear regression analysis for female students also showed no significant correlation between their algebra score and any of the attitude factors.

A linear regression analysis was performed on the attitude variables, with the Lawson score as the dependent variable. The results are found in Table 27. Linear regressions were also performed controlling for gender. The results for male and female students are found in Tables 28 and 29, respectively.

Table 27. Linear Regression with the Lawson Score as the Dependent Variable
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	23.672	3.764		6.290	.000
	Value Physics Knowledge	-4.385	.966	-.576	-4.538	.000
	Prefers Traditional Practices	-1.529	.748	-.234	-2.043	.046
	Desire for Conceptual Knowledge	-.559	.680	-.090	-.823	.414
	Scientific Attitude	1.595	.759	.271	2.100	.040
	Meaningful Learners	.170	.928	.021	.183	.856
	Problem Solving	.878	.713	.143	1.231	.223

The results of the linear regression analysis found that the attitude variable Value Physics Knowledge was negatively correlated with the students' Lawson score. This result prompted additional linear regression analysis, controlling for student gender.

Table 28. Linear Regression with the Lawson Score as the Dependent Variable for Male Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	16.612	4.898		3.392	.002
	Value Physics Knowledge	-3.633	1.554	-.366	-2.338	.027
	Prefers Traditional Practices	-8.562	2.052	-1.129	-4.173	.000
	Desire for Conceptual Knowledge	.908	.707	.193	1.284	.210
	Scientific Attitude	7.917	1.581	1.314	5.007	.000
	Meaningful Learners	2.610	1.038	.404	2.513	.018
	Problem Solving	1.584	.741	.313	2.136	.042

The results of the linear regression analysis for male students show a negative correlation between Lawson score and the Prefers Traditional Practices attitude variable. There is also a significant correlation between the Scientific Attitude variable and the male Lawson score, as well as weak correlation with the Meaningful Learners variable.

Table 29. Linear Regression with the Lawson Score as the Dependent Variable for Female Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	32.335	3.356		9.635	.000
	Value Physics Knowledge	-2.046	1.580	-.239	-1.295	.208
	Prefers Traditional Practices	-2.353	.676	-.442	-3.480	.002
	Desire for Conceptual Knowledge	-2.262	.979	-.286	-2.310	.030
	Scientific Attitude	-.673	.749	-.131	-.898	.378
	Meaningful Learners	-3.664	1.185	-.424	-3.093	.005
	Problem Solving	2.662	.921	.418	2.891	.008

The results of the linear regression for female students also showed a negatively significant correlation between the Lawson score and the Prefers Traditional Practices as well as the Meaningful Learners attitude variable. There was a positive, significant correlation between the female Lawson score and the Problem Solving attitude variable. In contrast to the male data, Scientific Attitude is no longer a significant predictor for scientific reasoning skills.

A linear regressions analysis was performed on the attitude variables, with Reading score as the dependent variable. The results are found in Table 30. Additional linear regressions were performed, controlling for gender. The results for male and female students are found in Tables 31 and 32, respectively.

Table 30. Linear Regression with the Reading Score as the Dependent Variable

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	6.226	1.405		4.430	.000
	Value Physics Knowledge	-.100	.361	-.038	-.277	.783
	Prefers Traditional Practices	.252	.279	.111	.901	.371
	Desire for Conceptual Knowledge	-.189	.254	-.088	-.744	.460
	Scientific Attitude	-.491	.284	-.241	-1.732	.089
	Meaningful Learners	.191	.346	.069	.552	.583
	Problem Solving	-.732	.266	-.345	-2.749	.008

The linear regression analysis showed a weak correlation between the students' Reading score and the Problem solving attitude variable. This prompted the data to be divided by gender.

Table 31. Linear Regression with the Reading Score as the Dependent Variable for Male Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.938	1.484		5.348	.000
	Value Physics Knowledge	-1.163	.471	-.334	-2.471	.020
	Prefers Traditional Practices	-1.662	.622	-.623	-2.674	.013
	Desire for Conceptual Knowledge	.348	.214	.210	1.626	.116
	Scientific Attitude	.619	.479	.292	1.291	.208
	Meaningful Learners	1.032	.315	.454	3.279	.003
	Problem Solving	-.821	.225	-.461	-3.654	.001

The results of the linear regression analysis show that there is a negatively significant correlation between the Problem solving attitude variable and the male Reading score. There is also a positive, significant correlation between the Meaningful Learners attitude variable and the male Reading score.

Table 32. Linear Regression with the Reading Score as the Dependent Variable for Female Students

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	5.838	1.945		3.002	.006
	Value Physics Knowledge	-1.550	.916	-.470	-1.693	.103
	Prefers Traditional Practices	.753	.392	.368	1.923	.066
	Desire for Conceptual Knowledge	-.662	.567	-.217	-1.167	.255
	Scientific Attitude	-.549	.434	-.277	-1.264	.218
	Meaningful Learners	-.169	.686	-.051	-.246	.808
	Problem Solving	.732	.534	.299	1.373	.183

The linear regression analysis for female students showed no significance between their Reading score and any of the attitude variables.

CHAPTER 4

DISCUSSION

Linear Regressions with the Mechanics Baseline Final Score

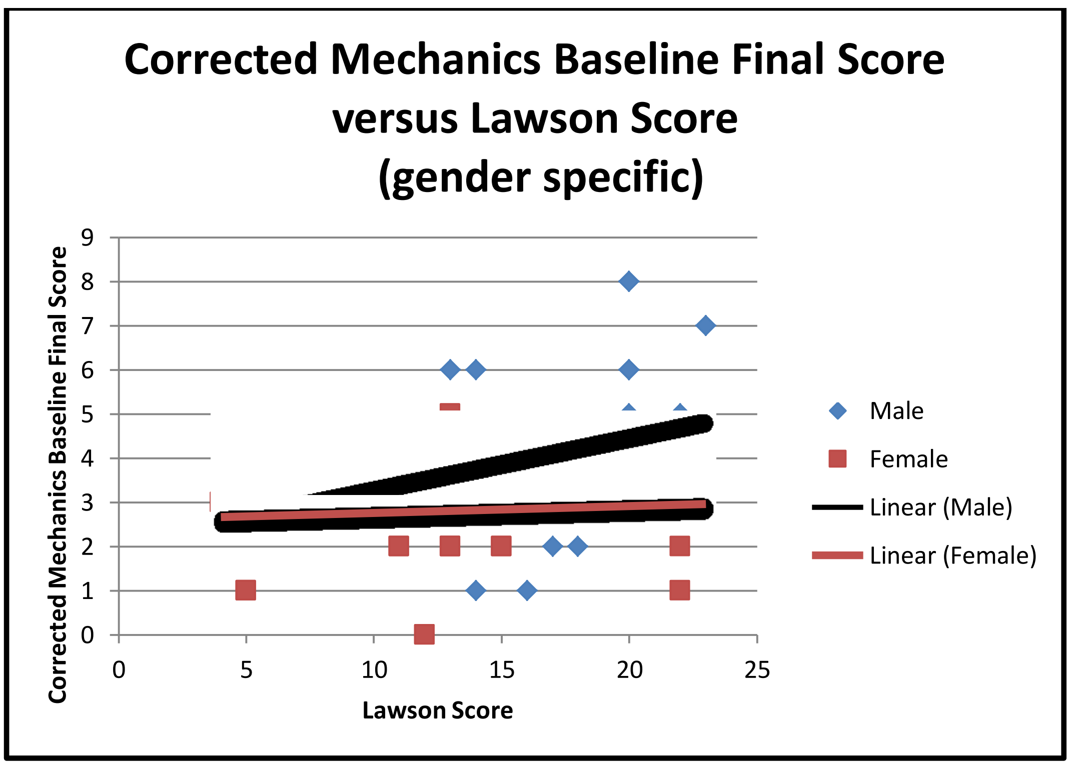
The linear regression analysis, using the Mechanics Baseline Final score as the dependent variable, showed only the significance of the pretest in predicting success on the Mechanics Baseline Final Test. This correlation with the pretest is supportive of the validity of using the Mechanics Baseline Final score as measure of the students' physics achievement. The linear regression performed with the Mechanics Baseline Final score as the dependent variable for male students found a significant correlation only between the students' pre and post test scores.

The linear regression analysis for the female students determined a positive, significant correlation between both the Algebra and the Mechanics Baseline Initial scores with the Mechanics Baseline Final score. The female students' Algebra score accounted for 72.1% of the variance in their Mechanics Baseline scores. This shows that for female students enrolled in an introductory physics course to learn physics concepts, they must possess algebraic abilities. Achievement in physics involves solving physics problems, which often requires the algebraic manipulation of mathematical expressions. So, this correlation shows females are using mathematical tactics to learn physics.

The linear regression analysis also found a significant, negative, correlation between the female students' score on the Mechanics Baseline Final Test and the

Lawson Test. This result means that female students that achieve in physics do not possess good scientific reasoning skills, or choose not to use scientific reasoning as a means for discerning the answer to a question. This result may indicate one of the sources of the gender gap. Scientific reasoning is crucial for solving physics problems. If female students choose not to apply this skill as a possible means for approaching physics problems, then lower female achievement scores are an obvious consequence.

A plot of both the male and female students' Lawson score versus their Mechanics Baseline Final score is shown in Figure 2. The plot shows that the score on



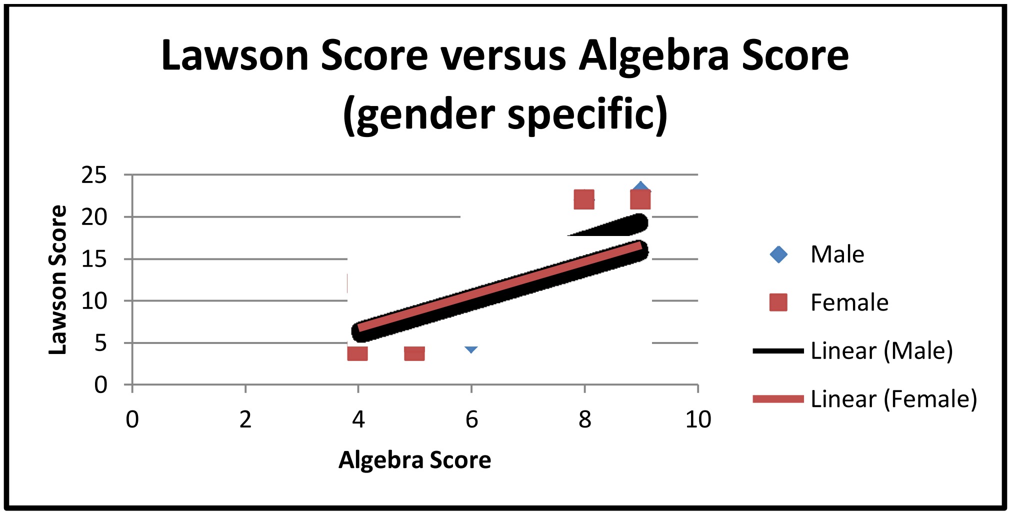
Graph 1. Plot of the Lawson Score versus the Mechanics Baseline Final Score.

the scientific reasoning test has almost no effect on physics achievement for female students. We can also see that a greater level of scientific reasoning ability does correspond to a greater level of physics achievement for male students. This plot provides a visual representation of the physics-learning gender gap.

Linear Regression with the Algebra Score

The linear regression analysis performed with Algebra score as the dependent variable found a significant correlation between the students' Lawson score and their Algebra score. The relationship between the students' Algebra and Lawson score shows a connection between scientific reasoning ability and algebra skill. This correlation could mean that both of these variables depend on a mental attribute that was not assessed in this study.

Linear regressions were also performed with the Algebra score as the dependent variable as the dependent variable, while controlling for gender. A plot of this data can be found in Figure 1. The plot clearly illustrates a relationship between student Algebra score and Lawson score, as well as showing a gap in performance between the two genders.



Graph 2. Plot of Algebra score versus the Lawson score.

The linear regression analysis for male students, with Algebra score as the dependent variable, found only a weak correlation between the Lawson and Algebra scores. This indicates that scientific reasoning skills are only somewhat dependent on algebra skill for male students. The linear regression for female students found significant correlations between both their Lawson and Mechanics Baseline Final scores and their Algebra score. These results show the interrelation between scientific reasoning and algebra skills, as discussed above. The results also show a necessity for female students to have mathematical skills to achieve in physics.

Linear Regression with the Reading Score

The linear regression analysis performed with the students' Reading score as the dependent variable found no significant correlation between the students' reading/comprehension skills and any of the proposed independent variables. These results were also found when controlling for gender. The lack of correlation between reading/comprehension and any of the investigated variables gives evidence for its removal from future work in the field of physics education research.

Linear Regression Summary

Overall, the linear regression analysis showed that female students did have significant predictors for success in physics, while none of the success factors were predictors for male students. This has been shown in previous research, but the question of male success still remains unanswered. The only significant predictor for performance on the Mechanics Baseline Final Test was their performance on the Mechanics Baseline Initial Test. This result serves to indicate the validity of the Mechanics Baseline Test, but also shows that male students may excel in physics due to prior exposure to the material.

Reliability of the Mechanics Baseline Test

A Cronbach's Alpha reliability test was performed on the selected problems from the Mechanics Baseline test administered at the beginning and end of the semester. The Cronbach's Alpha value for the Mechanics Baseline Initial Test was 0.172, while the value for the Mechanics Baseline Final Test was 0.436. It would seem as though the Mechanics Baseline Test is an unreliable tool for gauging physics knowledge. However, the value found for the post-test does indicate that the test is somewhat reliable. The explanation of the unreliability of the pre-test is that the students' incoming knowledge of physics was so little that there was guessing on every problem. The Mechanics

Baseline Test is a widely accepted and reliable tool for assessing students' abilities in introductory physics. The low reliabilities of the pre- and post-test may indicate that the questions on the Mechanics Baseline Test are too difficult for students in an algebra-based introductory physics course or that the number of questions used was too small for an accurate evaluation of the students' abilities.

Reliability of the Algebra Test

The Cronbach's Alpha reliability analysis of the Algebra skill assessment revealed that the test created does not accurately gauge the student's mathematical abilities. This is likely due to the relative ease of the assessment. The second question was answered correctly by all 64 participants in the study. Questions 1 and 9 yielded a negative correlation value, which indicates the need for their removal from the algebra assessment. It is possible that Question 9 is representative of more than one dimension of meaning, being that it required the creation of the set of algebra equations from a fictional scenario and then the solving of those equations. However, this is not the case with Question 1, which was a simple linear equation. The low correlation values indicate that the set of mathematical skills tested was too limited and should be expanded for further studies.

Reliability of the Lawson Survey

The reliability analysis on the Lawson Test determined a Cronbach's Alpha value of 0.830, indicating that the results found in this study were very reliable in gauging a student's scientific reasoning abilities. The individual item analysis found one negative correlation that could indicate some systematic error. Further analysis showed that the question's difficulty is responsible for the correlation value.

Attitude Linear Regressions with the Mechanics Baseline Final Score

The data collected from the Massachusetts Physics Expectations (MPEX) survey was collected and a varimax rotation was performed on the data set. The resulting matrix was then arranged into an ordered rotated component matrix, which shows the groupings of related statements. The related questions were given descriptive labels and became a new set of variables for analysis. The six attitude factors determined by the varimax rotation analysis can account for almost sixty percent of the variance in the attitude responses.

The linear regression analysis performed for male students, with the Mechanics Baseline Final score as the dependent variable, found the pre-test as well as the Desire for Conceptual Knowledge attitude variable to be a significant predictor of physics achievement. This analysis has yielded the first result of the study that has shown a factor contributing to male achievement in physics. There is also a weak correlation between physics achievement and the Meaningful Learners attitude variable. Having the desire for conceptual knowledge may be the key to male success in physics courses.

The same linear regression analysis performed for female students did not find the Desire for Conceptual Knowledge or the Meaningful Learners attitude variable to be significantly correlated. Instead, there was a weak positive correlation between both the Prefers Traditional Practices and the Scientific Attitude variables and physics achievement. If female students have less desire to obtain a true conceptual understanding of the ideas and theories of physics then it should become less surprising that their achievement scores are lower than those of their male counterparts.

The weak correlation between the Prefers Traditional practices attitude variable and physics achievement shows that female students are accepting the current educational model used in their physics course. It may be culturally related that female students have embraced a style of teaching presented to them instead of seeking out one that can increase their understanding of the information presented in class. The promising result is the weak correlation between the scientific attitude variable and physics achievement. Female students that do well in physics do have a better scientific attitude than those that do not. If we can foster an environment so that female students can obtain a desire for conceptual knowledge, the reduction of the gender gap may by expected.

Attitude Linear Regressions with the Lawson Survey

The linear regression analysis performed with the students' Lawson score as the dependent variable found that the students' Lawson score was negatively correlated with the Value Physics Knowledge Variable, but when one analyzes the group by gender this significance is no longer present. Meanwhile, the linear regression for male student found that their Lawson score was significantly correlated with the attitude variable Scientific Attitude. Since the Lawson test gauges a student scientific reasoning abilities, this relationship is expected. There is also a significant, negative correlation between the students' Lawson score and the Prefers Traditional Practices attitude variable. This means that students with scientific reasoning skills do not prefer the lecture-centered classroom environment. This may indicate that the classroom environment may be one of the factors keeping male students with an aptitude for physics from pursuing physics as a career.

The linear regression analysis for female students, with Lawson score as the dependent variable, found a significant correlation between the students Lawson score and the Problem Solving attitude variable. Scientific reasoning involves the use of deductive reasoning and the application of scientific principles, so the correlation between a problem solving attitude and scientific reasoning is understandable, yet was not found in the male group. This may be another piece of evidence that the female group is relying on other academic tools to solve physics problems. There are also a significant, negative correlation found between both the Prefers Traditional Practices and the Meaningful Learners attitude variable with the students' Lawson score. The mirroring of the female students', with good scientific reasoning skills, aversion to the lecture-centered classroom environment provides more motivation for the implementation of a different classroom setting.

The Meaningful Learners attitude variable was also found to have a negative, significant correlation with the female students' Lawson score. This result becomes more meaningful when it is taken in conjunction with the negative, weak correlation between the female students' Desire for Conceptual Knowledge and their Lawson scores. Meaningful learning implies that the concepts to be learned are fully understood as well as how the specifics of the concepts relate to other concepts. It appears as though female students with scientific reasoning abilities are less meaningful learners because they have less desire for conceptual understanding. This is another possible source for the gender gap.

Attitude Linear Regressions with the Algebra Score

The linear regression analysis performed with the students' Algebra score as the dependent variable found that none of the attitude variables were significantly correlated with the student's Algebra score, for either gender. Since the result of this set of linear regressions did not match the set of linear regressions performed with the Mechanics Baseline Final score as the dependent variable, it can be concluded that the attitudes required for mathematics and physics are not the same. This may be an indication that mathematics and physics are viewed as considerably different processes to students.

Attitude Linear Regressions with the Reading Score

The linear regression analysis on male student data with their Reading score as the dependent variable found significant correlation between the Reading score and the Meaningful Learners attitude variable. There was also a negative significant correlation between reading score and the Problem Solving attitude variable, as well as a weak negative correlation between the Reading score and the Prefers Traditional Practices attitude variable. These relationships were not mirrored by female students; none of the attitude variables were found to have a significant correlation with the female Reading score. The meaning behind these relationships is convoluted and should be examined by further studies attempting to find a link between student attitude and reading/comprehension levels.

CHAPTER 5

CONCLUSION

Summary

The results of the Mechanics Baseline Test found that male and female students had an average score of 4.2 and 2.8 out of 9 on the Mechanics Baseline Final Test, respectively. Also, 25% of the students in the study performed worse on the post-test than the pre-test. The results of the study indicate that the traditional practices of teaching physics at the university level do not increase student physics understanding at a high level. These results mean that alternative educational methods, outside of the lecture-centered model, must be considered. There have been positive preliminary results for a student-centered educational environment. Even though this comes with a drastic increase in cost of operations, physics departments have a fundamental responsibility to educate students enrolled in physics courses.

Separation from traditional practices may also be the solution for increasing the number of students entering the field of physics. The linear regression analysis, shown in Tables 28 and 29, determined that both male and female students that possess scientific reasoning skills do not prefer traditional practices of education. These students with the aptitude for physics may be more likely to the field if placed in an environment that they found more conducive to learning.

The linear regression analysis found that only females' success could be predicted by any of the academic factors proposed. Their performance on the

Mechanics Baseline Test was dependent on the score on the Algebra Test. This relationship shows that mathematical standards can be used when placing students entering introductory physics courses. Additionally, there was a negative correlation between scientific reasoning ability and physics achievement. This result, when coupled with the one above, indicates that female students are relying on mathematics and not reasoning to solve physics problems. This potential tendency against the application of scientific concepts to simplify a problem may be one of the sources of the gender gap in physics.

Female students' lesser algebraic skill can be remedied, without appearing to having different standards for male and female students. The implementation of a mathematics skills assessment for all students enrolling in an introductory physics course may solve this disparity. If students have a determined minimal level of mathematical competency, then they are allowed to enroll in the physics course. If they do not, then they would need to complete a mathematics course that would ensure they have the mathematical skills required to be successful in their desired physics course.

The lack of application of scientific reasoning is far more difficult undo. Using scientific reasoning is not a skill that someone obtains over night. It is a skill that must be built over time. The choice not to apply scientific reasoning to a physical situation also could not have occurred overnight. Female students seeking alternative strategies besides scientific reasoning must have developed since secondary or even late primary school. The solution to this must start with an evaluation of the gender-based cognitive process and then an intervention to correct any missteps in their problem solving process.

Conversely, male students' physics achievement could only be predicted by their pretest score. This result was mirrored in female students as well. The fact the student success can be predicted by their previously acquired physics knowledge is expected. The analysis did not provide any academic factor that contributed to male students' success in physics. What the linear regression analysis in Table 3 and Table 4 did show is that the success factors for male and female students are strikingly different.

If the above results are the source of the gender gap, its reduction or elimination will take time. The process of determining the reasons for the female avoidance of scientific reasoning and fixing this could take years of investigation and intervention. Educators need to take steps to ensure that the students enrolled in physics courses are educated in a manner that will maximize their educational experience. There are several avenues to achieve this, but the simplest may be to separate students into groups based on their educational identities and design curriculum that best suits these groups' learning and problem solving styles.

The source of the gender gap may not be localized to academic abilities. The results of the linear regressions with attitude variables, created by the varimax rotation analysis, found that there were significant predictors for male physics achievement. The results from Table 23 show that male students' desire for conceptual knowledge is a significant predictor of physics achievement. This attitude was not shared by female students that achieved in their physics studies.

The attitudes of the female students that do succeed in physics were shown to have a scientific attitude, but they also seemed to prefer the traditional educational practices. This relationship points to female students' willingness to accept the environment presented to them. However, if this educational setting is not conducive to their learning, female students may not seek out the environment, outside of class, that can help them gain a grasp on physics concepts.

Both the Lawson Classroom Test of Scientific Reasoning and the Maryland Physics Expectations survey were shown to be reliable tools for gauging scientific reasoning skills and student attitudes, respectively. The Mechanics Baseline Test was found to only be somewhat reliable from the results of its second administration and not reliable in its first. This unreliability in the initial test is most likely due to students' unfamiliarly, or lack of exposure, to physics. The reliability of the final test shows that the Mechanics Baseline Test may be comprised of problems too difficult for an algebra-based physics course.

Interventions

The results of the study have identified several areas for educators to make improvements. These are both within the academic realm as well as interventions attempting to alter student attitudes. These interventions are not limited to a university classroom or curriculum; there are also actions that can be taken at the K-12 level that will address the problems found at the collegiate level.

At the collegiate level, a physics instructor has little influence on their students' scientific reasoning background. Since scientific reasoning and algebraic skills were found to be significantly correlated to student success, universities need to ensure that the students are prepared to succeed in the courses they enroll in. Universities can administer an exam to determine if students have the skills necessary to succeed in introductory physics courses. This test can be given at a university testing center or in a web-based format, with the results determining whether a student can enroll.

This exam can be comprised of both mathematical and scientific reasoning questions. Physics departments can take several actions in response to students who do not score at a satisfactory level. One option is to offer a lower level physics course that emphasizes basic science, scientific reasoning, and that enhances mathematics skills. Students with low scores on the entrance exam could be required to take the above mentioned course before they can enroll in introductory physics.

If forcing students to take an additional course does not appear viable to a physics department, instead they could offer two sections of the same course, for instance one that meets four times a week and another that meets five times. All students, regardless of their entrance score, would attend the same lectures and labs. But the students with below satisfactory entrance scores would have an additional class period where they could work to improve their scientific reasoning skills or be given additional help with the mathematics that is required for the current material.

University physics departments also need to respond to the low learning gains by students in their introductory physics courses. One change that has led to student learning gains is a change from the lecture-centered classroom to a student-centered classroom. Understanding that this change carries an increase in the cost of operation, it appears to be warranted if students have an increased understanding of the material as well as having an improved attitude about physics subject matter.

These interventions at the university level can also be more proactive. Understanding that there is little intellectual growth occurring in the three months between finishing high school and starting college, universities can create a bridging program for incoming freshman that are planning on enrolling in introductory physics. This can be offered in the summer months, and can focus on improving algebra and scientific reasoning skills. If there is going to be a change to the student-centered classroom model, this would also serve as an introduction to cooperative learning, since it will be an entirely new experience for most incoming students.

This bridging program can also address the epistemological needs of students, addressing how individual students learn. An individual's understanding of how they learn in a science course is a valuable tool if they are going to be pursuing a science degree. There are several tests that can be administered to the students during the summer bridging program that can help them understand what they will need to do, individually, to succeed.

This study also determined that student attitude is also a significant predictor of physics achievement, and the only indicator for male students. But a student's attitude is not something a professor can change quickly, in the first month of a course, so that a student will succeed in the course. Changing student attitudes must be addressed at the secondary or even primary school level. This study found that a particular learning identity, comprised of a specific set of attitudes, had the most success in learning physics. The acquisition of this set of characteristics should be the goal of research at the K-12 levels.

Male physics achievement was determined to depend on only two attitude variables: the desire for conceptual learning and being a meaningful learner. Research needs to be completed that determines not only when male students obtain these attitudes, but also when female students lose them. The identification of this point can allow for educators to make changes to their teaching methods that can foster these attitudes in all students. If a student does not want to understand the material in a course, educators cannot expect that they would achieve at the same level as the student who do have a desire for conceptual understanding.

Until the point where this divergence in learning identity can be identified, changes can be made to ensure that all students are maximizing their potential. It may best for these groups of students to be separated in middle school or elementary school, and receive an educational curriculum that is best suited to their learning identity. This can be accomplished through separate science classes in middle school. This can be done at the elementary level, or one science class can be split into two groups with separate instruction to improve the learning of both groups.

Future Works

The study preformed was conducted on a set of students enrolled in a traditional learning environment, a lecture-centered course. One of the conclusions drawn from the results was that the lecture-centered model does not allow of the maximal student achievement, and that a change to student-centered practices should be considered. For this claim to be justified, the study would need to be repeated for a set of students in a student-centered environment to verify that student achievement levels are greater than those reported in this study.

This study found that algebra ability appears to be significantly linked to female performance. However, the tool used to assess this ability failed to meet reliability standards. It is believed that expansion of the mathematical skills assessed would increase the test's reliability and possibly transform the Algebra assessment into a tool that would successfully show a correlation between it and student performance both male and female students.

The Mechanics Baseline is a proven tool for assessing the mechanics knowledge of students in physics courses. The selected problems used in this study seemed to be valid evaluation tools because of the significance of the pretest in predicting performance on the post test. But the reliability analysis of the selected problems from the Mechanics Baseline Test failed to meet the required standards, and the pre and post had very different Cronbach's Alpha values. This result indicates that the Mechanics Baseline Test is not the proper assessment tool for an introductory algebra-based physics course. Other evaluation means should be sought out for analysis.

The results of the Student Expectation Survey showed an interesting set of student attitudes that were negatively correlated with the hypothesized results. Further exploration of these student beliefs may provide insight into the source of poor performance of non-majors in introductory physics courses. Also, the habits assessment showed that cooperative work was generally thought to be beneficial by students when working toward a graded objective and not otherwise. This may also be a source of low student performance and should be further investigated.

The lack of results for male students is puzzling. It would suggest that the factors that lead to female success have no bearing on male success. Perhaps, male students have had much more exposure to the material being covered in the course or other untold advantages. There seems to be some disparity in ability to scientifically reason, but seeing as this was not a significant in predicting male student success more research into the success factors of male student performance is warranted.

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