STUDENT ATTITUDE TOWARD STEM: DEVELOPMENT OF AN INSTRUMENT FOR HIGH SCHOOL STEM-BASED PROGRAMS

Dissertation

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By

Mark Patrick Mahoney, M.A.

College of Education and Human Ecology

The Ohio State University

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Dissertation Committee:

Karen F. Zuga, Advisor

Donna F. Berlin

Jerome V. D'Agostino

ABSTRACT

Expansive amounts of money and time have been provided in the hopes that STEM based programs will boost student interest and abilities related to STEM. Financiers include national government and industrial organizations. However, these investments have yielded little results as demonstrated by the continued reports being disseminated each year demanding greater STEM investment and results. The development of an instrument that can accurately measure student attitude toward STEM is crucial to STEM-based programs, their intended outcomes, and the companies that aid in their function as well as hope to reap the benefits from their products.

The intent of this study was to develop an instrument to measure the current level of attitude that students' exhibit toward STEM and STEM education. A variation of the Concerns-Based Adoption Model, Taxonomy of Education Objectives – Handbook II, and other pertinent instruments were utilized as sources of inspiration for the development of the instrument. The developed and selected items were submitted to a panel of experts representative of STEM and STEM education. Initial pilot testing refined the instrument through principal components analysis and Cronbach's alpha coefficients. Three principal components were identified by the researcher – interest, ability, and value. The identified principal components aligned well with reviewed attitudinal instruments. Reliability coefficients were strong for each of the identified principal components – coefficients were above .70 alpha.

Concurrent validity was also established for the pilot study by comparing the data analysis results obtained from the student attitude toward STEM instrument with the results from a semantic differential attitudinal instrument. The example of concurrent validity provided by the Pearson product moment correlation between the two attitudinal instruments only applied to the student attitude toward STEM instrument used for the pilot study. Both attitudinal instruments were included in the pilot study instrument packet provided to the high school students. A statistically significant moderately positive correlation was demonstrated between the two instruments as indicated by the Pearson product moment correlation.

A student focus group was used to review the pilot instrument and the instrument items. The students provided valuable face and content validity regarding high school student interpretation of the instrument. Results of the combined analyses led to revisions of the instrument prior to a larger comparative study – a known-group comparison. A self-identified STEM-based high school program and a conventional college-preparatory program were compared in the known-group comparison. Principal components analysis and Cronbach's alpha procedures were again applied to the data collected from the revised instrument. The two samples were compared using three distinct independent variables – educational location (type of school), grade level (ninth-grade and eleventh-grade), and gender (male and female). Each independent variable was analyzed for each of the researcher identified principal components: interest, ability, and value.

Hypotheses were designed and tested for each of the independent variables. The hypotheses were used in an attempted to provide another example of construct validity

for the revised student attitude toward STEM instrument. MANOVA procedures along with follow up univariate analyses and non-parametric analyses procedures were applied to the student responses to the revised STEM attitudinal instrument. Assumptions regarding homogeneity of variance and normality were also carried out for the statistical procedures. Homogeneity of variance was maintained for the majority of independent variable reviewed with violations being specific to certain content areas or singular attitudinal levels. Normal distributions were not demonstrated by the majority of the independent variable samples; the distributions were primarily negatively-skewed.

According to the results of the data analyses, the male students indicated a statistically significant more positive attitude toward STEM when compared to the female students for the independent variable of gender. The statistical significance was demonstrated specifically for the content areas of technology and engineering. The results of the data analysis supported the proposed hypothesis for the content area of technology and engineering and provided the revised student attitude toward STEM instrument with an example of construct validity. The data analyses of the independent variables of school and grade level did not provide statistically significant results. The null hypotheses of for these two independent variables were retained.

Based upon extensive review of the varied data analysis procedures implemented, the student attitude toward STEM instrument demonstrated positive examples of validity and reliability. The results of the exploratory research study are promising for the development of a useful attitudinal instrument as well as powerful tool for STEM education. Future research with larger and more varied sample sizes will aid in the

development and refinement of the student attitude toward STEM instrument. This study and the resulting attitudinal instrument are imperative steps toward increasing the accountability and design of quality STEM educational programs.

DEDICATION

"The most important things in life are your friends, your family, your health,

a good sense of humor, and a positive attitude toward life.

If you have these things, then you have everything"

- Author unknown

To my family and friends,

Thank you for all your love and support.

It is to you that I owe my success,

it is to you that I owe my sanity.

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To my colleagues and friends: I thank you for your support and kindness.

To my family back home: I thank you for your love and understanding.

To my future wife: I could not have accomplished this without you. I am blessed to have you in my life.

To you all, I am eternally grateful.

VITA

September, 1979 ....Born: Norwalk, Connecticut

2001 ....B.S. Education,
Central Connecticut State University

2001 – 2002.. High school and middle school classroom teacher,
Old Saybrook, Connecticut

2002 – 2005... High school classroom teacher,
Glastonbury, Connecticut

2002 – 2005...E-4, Connecticut Army National Guard

2005 – 2009..Graduate teaching assistant/Instructor,
The Ohio State University

March, 2008 ....M.A., Technology Education,
The Ohio State University

Presentations

Mahoney, M. (2007, March). *Technology education: an engineering stepping stone?* Presented at the annual conference of the International Technology Education Association, San Antonio, TX.

Mahoney, M (2008, May). *Student interest in STEM: Development of an instrument.* Presented at the National Center of Engineering and Technology Education, Minneapolis, MN.

Mahoney, M. (2009, March). *Measuring student attitude toward STEM: Development of an instrument.* Presented at the annual conference of the International Technology Education Association, Louisville, KY.

Fields of Study

Major Field: Education

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CHAPTER 1: INTRODUCTION

In 1983, *A Nation at Risk* (National Commission on Excellence in Education [NCEE], 1983) established the resurgence for the science, technology, engineering, and mathematics (STEM) movement in education. In the 1980s, a gradual change in economic strength was occurring, transferring power from domestic industries to foreign markets. Though the history of this trend can be traced back 20 years, it was the *A Nation at Risk* (NCEE) report that brought the reality to the publics' attention.

> The time is long past when American's destiny was assured simply by an abundance of natural resources and inexhaustible human enthusiasm, and by our relative isolation from the malignant problems of older civilizations. The world is indeed one global village. We live among determined, well-educated, and strongly motivated competitors. We compete with them for international standing and markets, not only with products but also with the ideas of our laboratories and neighborhood workshops. America's position in the world may once have been reasonably secure with only a few exceptionally well-trained men and women. It is no longer. (p. 10)

The influence of this report and its recommendations are echoed in the feverish development of national standards produced by academic organizations such as the National Council of Teachers of Mathematics (NCTM), the American Association for the Advancement of Science (AAAS), the National Research Council (NRC), and the

International Technology Education Association (ITEA). Each educational organization was in the process of producing preliminary documents by the close of the 1980s. It is within this process that we may witness the first inclinations of STEM. NCTM (2000), AAAS (1989), NRC (1996) and ITEA (2000) documents all suggest the combination or integration of their respective subjects in an attempt to enhance student learning and STEM preparation.

In the NCTM's *Principles and Standards for School Mathematics* (2000), students are encouraged to "pursue an educational path that will prepare them for lifelong work as mathematicians, statisticians, engineers, and scientists" (p. 4). The AAAS document, *Science for All Americans*, defines a scientifically literate person as "one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations" (p. 4). ITEA(2000) rounds out these examples in the following excerpt from the *Standards for Technological Literacy*: *Content for the Study of Technology;* "Technology is not simply one more field of study seeking admission to an already crowded curriculum…it reinforces and complements the material that students learn in other classes" (p. 6).

This proposed subject integration has taken many forms since the overall arrival of standards. Programs, modules, packaged curriculums, and even charter schools have aligned themselves with proposed models of what a STEM educational program should represent. A recent report by the Academic Competitiveness Council ([ACC], 2007) indicates that there are up to 105 government-funded STEM education programs in the

United States, ranging from kindergarten to post-graduate education. Included in this estimate are outreach programs, such as weekend, after school, and summer programs. The report by the ACC also collected information regarding the cost associated with STEM education programs. Overall estimates indicate total government expenditure to exceed $3.12 billion over the 2006 fiscal year. These monies are supplied through a variety of government foundations – predominately by the National Science Foundation (NSF) at 29%, the Department of Health and Human Services (HHS) at 27%, and the Department of Education (DoE) at 23%.

Evaluations of these programs were also collected and reviewed (ACC, 2007). The evaluations were referenced in order to review the proposed effectiveness of the STEM programs in addition to the quality of the evaluations themselves. Unfortunately, it was found that the majority of the evaluations were below the expectations of the council. In fact, those that did display potential still required revisions to add greater validity to the information provided. This is not a new occurrence. NSF has been revising its own grant procedures to account for this lack of efficient evaluation. Educational research grants such as Innovative Technology Experience for Students and Teachers (ITEST), Research and Evaluation on Education in Science and Engineering (REESE), Discovery Research, K–12 (DR-K12), and Informal Science Education (ISE) now require a more in-depth evaluation format than previous documentation (NSF, n.d.). Typically these evaluations now require a third-party review in addition to multiple and frequent progress reports. Programs funded by NSF and other organizations have carried on for years with government money without providing sufficient information or measurable influence upon the educational community (ACC).

Add to this condition, the limitless number of private industries that have produced and sold STEM educational products and curriculums over the last 20 years. These varied items align themselves with national standards and suggest educational advancement in the form of problem solving, cooperative learning, and subject integration. Some of the more popular examples associated with implementing principles of STEM are: Project Lead the Way (PLTW), DesignQuest (PTC), and Engineering byDesign (EbD). However, very little research has been conducted regarding the degree of influence upon education or even student learning (ITEA, n.d., PLTW, 2005, PTC-MIT Consortium, 2006). This is not to suggest that any of the programs or institutions engaged in STEM endeavors are faulty – just simply that they require more reinforcement through proper research and evaluation.

A more recent development is the creation of entire educational institutions devoted to STEM development. These schools are not vocational or career and technical institutions, but rather college preparatory programs designed to develop student abilities and interest in STEM and STEM careers.

Problem Statement

STEM-based educational programs and institutions have been developed to address the national need for engineers, technicians, and scientists. Several national organizations have displayed great interest in such development. In 2004, the Education Commission of the States (ECS) issued the report *No Time to Waste: The Vital Role of*

College and University Leaders in Improving Science and Mathematics Education. According to the report, the American STEM workforce has quadrupled over the last 20 years. Conversely, the number of students preparing for careers in STEM has been either stagnant or declining. An interesting correlation is noted in the ECS report to address this condition.

> [C]lassroom access to computers and the internet had expanded significantly, as has the availability of Advanced Placement science and mathematics courses. Nearly all states have established academic standards in both science and mathematics, and the annual testing of students in core subjects mandated by the No Child Left Behind Act will be extended, in the 2007–08 school year, to include science. Still, on a number of key indicators, America's systems of science and mathematics education continues to perform below par. (2004, p. 3)

The recommendations from this report consisted primarily of increased science and mathematics abilities for future teachers as well as greater exposure and collaboration with industry (ECS, 2004).

In 2005, the report *Tapping America's Potential* (Business Roundtable) produced a summary of the concerns from a variety of local professional organizations: American Electronics Association, Business-Higher Education Forum, Business Roundtable, National Defense Industrial Association, TechNet, and several more. The report cited warnings in the form of a declining STEM equipped population, increased foreign competition, low student interest toward engineering, low student achievement, and declining research funding (Business Roundtable). This collection of warnings from the Business Roundtable reinforces the growing amount of concern existent in American industry. The American Electronics Association (AeA) also shared their concern through the following statement in 2005: "America needs to recognize that future innovation is not predetermined to occur in the United States. Even if we were doing everything right, we still face unprecedented competition from abroad” (p. 3).

Many of the same organizations have invested in educational programs and institutions based upon principles of STEM in hopes of reversing these common concerns. Large amounts of money and time have already been provided in the hopes that these educational institutions will reinforce student attitude and abilities related to STEM. However, these donations have yielded little results as demonstrated by the continued reports being constructed each year demanding greater STEM investment and results. The development of an instrument that can accurately measure student attitude toward STEM is crucial to STEM-based programs, their intended outcomes, and the companies that aid in their implementation as well as hope to reap rewards from their products.

Interest was first sought as the focus of the instrument to be developed. This reasoning was based purely from observation and reflections of the current condition regarding the product of STEM programs as they exist. The term was used generally to describe what seemed to be occurring to students involved with the subjects of STEM. Attitude was selected later after extensive review of literature. This change was made so that an instrument capable of providing valuable information along a collection of possible components related to educational experiences could be constructed.

Additionally, math and science proficiencies for students engaged within these programs typically remain steady or are improving. So, why aren’t the students following through to higher levels of STEM associated learning? Why aren’t they interested? It is therefore imperative to know if STEM-based schools are actually developing positive student attitudes toward STEM and STEM careers. An instrument must be created that is widely available and applicable to accurately measure student interest in STEM. Data provided by such an instrument could inform STEM-based programs as to the value of their programs: specifically the projected influence upon improving the STEM workforce at large. Additionally, the supporting agencies of such educational programs, like STEM-based schools, would be clued in to the worth and necessity of their current investments; thereby better determining educational investments based upon research and not hopeful outcomes. It is from these combined conditions that the problem of this study is directed toward the lack of an existing instrument capable of measuring students' attitude toward STEM.

Research Question

The research question addressed in this study is built upon the lack of an existing instrument capable of measuring student attitude toward STEM. Extensive review of related attitudinal research revealed that attitudinal instruments are dependent upon the intended application and population. Provided this specific situation, the attitudinal instrument would have to measure across four content areas. A current instrument associated with attitude does not exist that can perform such a task. Therefore, the singular research question is as follows:

1. Can a reliable and valid instrument be created to measure student attitude toward the four content areas of STEM?

Objectives of the Study

The principal objectives of this study were as follows:

1. Construct a new attitudinal instrument.
    a. To create and identify categories specific to student attitude toward STEM based upon review of research and literature.
    b. To create and identify items specific to each of the established attitudinal categories intended to measure student attitude toward STEM.
    c. To establish reliability and validity of the student attitude toward STEM instrument.
2. To test the validity of the instrument between groups of anticipated difference.
    a. To test mean scores between the STEM-based high school and college-preparatory high school students across all dependent variables and content areas.
    b. To test mean scores between the ninth-grade level and eleventh-grade level students across all dependent variables and content areas.
    c. To test mean scores between male and female students across all dependent variables and content areas.

Hypotheses

From the research question, the objectives of the study and a review of the literature, the following hypotheses were produced:

H_1a: Students enrolled in a STEM-based college preparatory program will exhibit a more positive attitude toward STEM than students enrolled in a conventional college-preparatory program.

H_0a: Students enrolled in a STEM-based college preparatory program will not exhibit a more positive attitude toward STEM than students enrolled in a conventional college-preparatory program.

H_1b: Students exposed to STEM education for a longer period of time (i.e., higher grade level) will exhibit a more positive attitude toward STEM than students enrolled for a shorter duration (i.e., lower grade level).

H_0b: Students exposed to STEM education for a longer period of time (i.e., higher grade level) will not exhibit a more positive attitude toward STEM than students enrolled for a shorter duration (i.e., lower grade level).

H_1c: Male students will exhibit a more positive attitude toward STEM than female students.

H_0c: Male students will not exhibit a more positive attitude toward STEM than female students.

Assumptions of the Study

This study was based on the following assumptions:

1. The respondents accurately and honestly responded to the questionnaire.
2. The respondents provided information independently as directed by the researcher.
3. The interpretation of the Concerns-Based Adoption Model's Stage of Concern instrument was as reliable and valid in this study to the same extent as it has been in prior studies.
4. An adequate sampling of items necessary to measure student attitude toward STEM was obtained.
5. The sample(s) acquired for this study were large enough to provide sufficient item analysis data.
6. Student attitude toward STEM was reliably and validly measured through the application of a questionnaire.
7. A panel of experts in or related to the field of STEM and STEM education identified relevant items to aid in the measurement of student attitude.

Delimitations of the Study

The study was conducted under the following delimitations:

1. The study focused upon selected high school students and their STEM subject attitudes. Characteristics of the teachers, the instructional materials, the community, and other variables were not considered directly.

2. The study considered a STEM-based high school, as publicly claimed by the school via documentation or other media sources.
3. The study considered a college-preparatory high school, as publicly claimed by the school via documentation or other media sources.
4. The study only considered available high schools located within a singular metropolitan area.
5. Schools not identified as associated with the STEM-based school were not to be included in the study.
6. A representative sample of the high schools from within the STEM-based high school pooling network was employed rather than the entire available population.

Limitations of the Study

1. This study was limited to the available population of high school students on the day of implementation.
2. Schools that are associated with the STEM-based program may not have been identified and therefore not considered for a viable sample for the study.
3. Signed parent and student permission forms were required to be completed in order to include student data in the study.
4. Variables aside from those studied could have significant influence upon the results of the collected data. This includes students' definitions of the STEM content areas that may vary from the classroom expectation.

5. Total random selection of subjects from the population was not possible due existent classroom assignments and student scheduling. A convenience sample was drawn from intact classes within the chosen school systems.

Definition of Terms

For this study, the following terms were operationally defined for this research:

- STEM – The combined elements of science, technology, engineering, and mathematics. A combination of these subjects may be found in both educational and professional environments: typically self-identified and publicly displayed through a variety of media (NSF, 2009; University of Massachusetts, 2009).
- STEM career – A position of employment that utilizes the combined skills and abilities associated with STEM: typically identified as a position of need by national, local, and private organizations associated with the STEM fields. These positions include, but are not limited to, scientist, engineer, technologist, tradesperson, craftsperson, and/or inventor (STEM Career, 2009).
- STEM-based program – An education environment that integrates the subjects of science, technology, engineering, and/or mathematics to enhance student learning: typically self-identified through a variety of media and/or official notice via state or investing industry (University of Massachusetts, 2009).

The remaining terms were constitutively defined for the research question:

- Affective characteristic – A mental characteristic related to emotion, such as attitude, interest, and value (Gay, Mills, & Airasian, P., 2006).

- Category – A classification of ideas and concepts in qualitative data analysis (Gay et al., 2006).
- Engineering – The profession of or work performed by an engineer. Engineers are problem solvers who search for quicker, better, and less expensive ways to use the forces and materials of nature to meet today's challenges. Engineering involves the knowledge of the mathematical and natural sciences gained by study, experience, and practice (American Society for Engineering Education, 2008).
- Integrated/Integration - The process of bringing all parts together into a whole (ITEA, 2000).
- Interpretive research – Collective, generic term for qualitative research approaches (Gay et al., 2006).
- Mathematics – Study of abstract patterns and relationships that results in an exact language used to communicate about them. Mathematics is also considered the science of structure, order, and relation that has evolved from elemental practices of counting, measuring, and describing the shapes of objects. It deals with logical reasoning and quantitative calculation, and its development has involved an increasing degree of idealization and abstraction of its subject matter (Encyclopedia Britannica, 2008; Webster-Merriam, 2008).
- Science – The systematic observation of natural events in order to obtain facts about them and to formulate laws and principles based on these facts. Science is the organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation. There are several sections of the

general body of knowledge relating to science such as biology, physics, chemistry, geology, or astronomy (Academic Press Dictionary of Science & Technology, 1992).

- Technology – Innovation, change, or modification of the natural environment that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities (ITEA, 2000).
- Technology education – A study of technology, which provides an opportunity for students to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities (ITEA, 2000).
- Technological Literacy - The ability to use, manage, understand, and evaluate technology (ITEA, 2000).
- Vocational Education – Training within an education institution that is intended to prepare an individual for a particular career or job (ITEA, 2000).

Organization of the Study

This study utilized the following organizational format:

- Chapter 1 introduced the research problem and provides the rationale for the study. The research question, objectives of the study, and the hypotheses to be tested were provided. Also included are the definitions, assumptions, delimitations, and limitations of the study.
- Chapter 2 provided the review of the literature relative to the study. This literature review presents information including an overview of STEM and STEM

standards, the need for STEM, current research, attitude documentation, and instruments.

- Chapter 3 described the rationalization of the instrument, the research model, the pilot study, the subjects, the instrument, and procedures for the analysis of the data.
- Chapter 4 presented the analyses utilized for the study. These analyses included item analysis, principal components analysis, Cronbach's alpha, mean score comparison, the MANOVA procedure, univariate analyses, the Kruskal-Wallis Test, the Levene's test, the Kolmogorov-Smirnov test, and the Shapiro-Wilk test.
- Chapter 5 concluded the study with the conclusions determined from the analyses. Recommendations based upon the conclusions were also presented for future research.

Chapter 1 Summary

Chapter 1 provided the statement and background of the problem relating to STEM education and student attitude toward STEM. Next, the research question and objectives of the study were presented along with the hypotheses to be tested. Also provided were the assumptions, delimitations, limitations, and necessary definitions of the study concluding with the organization of the study.

CHAPTER 2: REVIEW OF LITERATURE

This chapter provides a detailed review of the research and literature that was utilized throughout the completion of this study. The information presented within this chapter explores the development of the acronym STEM and the associated educational standards from which it was created. A variety of current and available STEM applications will be discussed in order to demonstrate the diverse interpretations of the acronym. The growing demand for STEM and STEM educational programs will be described as they are presently being sought from supporting organizations and institutions.

Also provided is a detailed review of the existing documentation and research pertinent to the development of the attitudinal instrument. Variables specific to the measurement of attitude will be reviewed and identified as they are supported by the presented documentation. Items of special significance to the study are the *Concerns-Based Adoption Model* and the *Taxonomy of Educational Objectives, Handbook II*.

Standards of STEM

The acronym STEM is representative of the following academic subject headings: science, technology, engineering, and mathematics. The primary function of the term STEM is to lessen the time and space attributed to identifying the individual subjects as their associated presence has become more prevalent. STEM's increasing popularity among educational organizations and private industries has allowed for the development of logical definitions from this simple acronym. The National High School Alliance (NHSA) defines STEM as "integrative approach to teaching and learning that draws on the foundations of each individual field to form a cohesive course of instruction" (NHSA, 2008, STEM/Index). The Alliance for Education, a county-wide partnership developed in San Bernardino, CA, has a more specific definition for STEM. According to this alliance, STEM is "an initiative for securing America's leadership in science, technology, engineering, and mathematics fields and identifying promising strategies for strengthening the educational pipeline that leads to STEM careers" (Alliance for Education, 2008, home page).

These two definitions provide a glimpse of the widespread implications regarding STEM, beyond the simple abbreviated text. However, STEM definitions can be found in varying formats. For instance, the STEM Education Coalition outlines the value of STEM education within their mission objectives. The coalition believes that STEM education has a vital role in "enabling the U.S. to remain the economic and technological leader of the global marketplace of the 21st century" (STEM Education Coalition, 2008, Objectives). The coalition is comprised of more than 40 groups invested toward the development of STEM education and careers. The STEM Education Caucus represents the coalition and its affiliates during congressional proceedings. The caucus focuses national attention on STEM education by asserting that…

> ”Science, Technology, Engineering and Mathematics (STEM) Education is responsible for providing our country with three kinds of intellectual capital: scientists and engineers who will continue the research and development that is central to the economic growth of our country; technologically proficient workers who are capable of dealing with the demands of a science based, high technology workforce; and scientifically literate voters and citizens who make intelligent decisions about public policy and who understand the world around them.” (STEM Education Caucus, 2008, Home page)

With the exception of the definition provided by the NHSA, most organizations are concerned with the products of STEM education and not its collaborative characteristics. This reality allows for several interpretations of STEM education, each attempting to increase an unidentified measure of STEM proficiency on what appears to be a national scale. However, the large amount of variety in defined meaning as well as application may produce less than desirable results from such educational programs. STEM programs should be assessed as to their influence toward their proposed products and revised as needed to assure quality and productivity.

A Nation at Risk

Over the last 20 years, the term “standard” has become a keystone within the STEM educational community. By definition, a standard is something established by authority, custom, or general consent as a model or example (Merriam-Webster, 2000). This term has been modified for its role in education to a “statement describing what a person should know or be able to do” (National Research Council [NRC], 2002, p. 2) or a “statement about what is valued” (National Council of Teachers of Mathematics

[NCTM], 1989, p. 2). To understand the implication of this effect, we must reflect briefly on how we as a system have developed to this point. The trend toward standardization became evident in the early part of the 1980s. *A Nation at Risk* (National Commission on Excellence in Education [NCEE], 1983) reported to the government the then current trends in the American educational system.

The opening paragraph of the report states:

> Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. … We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. (NCEE, 1983, p. 1)

A Nation at Risk (NCEE, 1983) cemented the need for greater national support and interest in what would become STEM education for the sake and protection of national security and economy. This national report also suggested that the schools are at the heart of this condition. It is within this report that the concept of national standardization first arises as a solution to the ‘failing schools.’ The restructuring of education through standards was proposed to enable American society to compete with the global market.

> We recommend that schools, colleges, and universities adopt more rigorous and measurable standards, and higher expectations, for academic performance and student conduct, and that 4-year colleges and universities raise their requirements for admission. This will help students do their best educationally with challenging materials in an environment that supports learning and authentic accomplishment. (NCEE, 1983, p. 8)

In 1989, the National Governors Association (NGA) endorsed the concept of national educational standards/goals. President G. H. Bush, and later President W. J. Clinton, committed to supporting the NGA and thereby established the National Educational Goals Panel (NRC, 1996) to aid in the creation of national standards. By 1989, educational organizations such as National Council of Teachers of Mathematics (NCTM) and the American Association for the Advancement of Science (AAAS) were already in the process of developing standards.

The International Technology Education Association (ITEA) would soon follow. Within each of these organization's documents, no direct mention is provided to develop or support a STEM initiative. However, what is provided are several interrelationships or connections that the employer of such standards may utilize. It is this common set of interrelationships that were spawned from the *A Nation at Risk* document and further reinforced by national standards for each subject that would aid in the development and identification of STEM as an area of interest.

Standards for Mathematics Education

In *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), the NCTM points out three primary reasons why their organization adopted standards: (a) to ensure quality, (b) to indicate goals, and (c) to promote change. It is from this reasoning that the NCTM document prescribes a national model for mathematics education. Key to this ideal was the formulation of goals centered upon the current information-focused society and not the preexisting industrial society that assisted in the original establishment of organized education. Goals suggested in this document include mathematically literate workers, lifelong learning, equal educational opportunity, and a holistically informed electorate.

In 1991, the NCTM published its second document, *Professional Standards for Teaching Mathematics*. This document was created to aid in the implementation of the initial mathematics standard curriculum by recommending specific standards for teachers and teaching. An item of interest suggested in this document was the recommendation of empowerment to students during instructional interaction. The NCTM was suggesting that teachers allow their students to build communities, rely upon self verification, reason, solve problems, and connect related subject concepts (NCTM, 1991). In addition, this document recommends processes and foci of evaluation to properly assess student knowledge in this new behaviorist and constructivist learning environment. This item would be more specifically addressed in 1995 by NCTM's document entitled *Assessment Standards for Mathematics Education*.

The current culmination of the NCTM standard development efforts can be found in their recent document entitled, *The Principles and Standards for School Mathematics* (NCTM, 2000). This single document addresses the combined efforts of all the previously mentioned documents while updating the material to address current educational concerns. Such an example can be seen in the updated societal goals as displayed in Table 1 in the document.

Area	Description
Mathematics for life	Mathematics can be personally rewarding and empowering. The foundations of life are more and more mathematical and technological.
Mathematics as a part of cultural heritage	Mathematics is one of the furthermost academic and societal successes of human-kind, and should be appreciated and understood for that achievement.
Mathematics for the workplace	Mathematical thinking and problem solving needed in the workplace has increased dramatically; in multiple professional areas.
Mathematics for the scientific and technical community	Students must pursue an educational path that will prepare them for the intensive careers that demand mathematical proficiency: mathematicians, statisticians, engineers, and scientists.

Note. Adapted from National Council of Teachers of Mathematics. (2000). *The principles and standards for school mathematics.* Reston, VA: Author, p. 4.

Table 1. The Principles and Standards for School Mathematics Societal Goals

Within these goals, as well as their associated content standards, interrelationships between other academic subject material can be identified. It is evident that within the framework of the mathematical societal goals is a recognition of the concept of real-world applications, technology, and problem-solving (refer to Table 1). Though the mathematics standards suggest possible interdisciplinary connections, no direct configuration is provided within the national documentation. There are several supplemental documents created from alternate organizations that provide varying interpretations of these connections, as is typical with the education community.

Standards for Science Education

In 1989, the AAAS published *Science for All Americans*. *Science for all Americans* was a primary outcome of the Project 2061 long-term efforts to establish literacy goals in science, mathematics, and technology. Project 2061 originally began in 1985, the last year Halley's Comet was visible from the surface of the earth. The numerical name for the project was then based on the comet's expected return year of 2061. Through the combined endeavors of major research/program organizations like AAAS and the National Council on Science and Technology Education (NCSTE), *Science for all Americans* was produced (AAAS, 1989).

Unlike the NCTM documents, *Science for All Americans* was a collaboration of a series of individual panel reports formulated for Project 2061. The panel reports varied in related subject matter, including biological and health sciences, mathematics, physical and information sciences and engineering, social and behavioral sciences, and technology. It is from this collection of works that the science organizations hoped to assemble content standards focused on scientific literacy defined as follows:

> *Science for All Americans* is based on the belief that the scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understanding key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (AAAS, 1989, p. 4)

Science for All Americans established the core of content for science education and the associated subjects of mathematics and technology. At approximately the same time that this work was released, a collection of teams were already working on what would become the *Benchmarks for Scientific Literacy* (AAAS, 1993).

The *Benchmarks for Scientific Literacy* (AAAS, 1993) differed from previous curriculum related documents. The benchmarks created a tool to assist a state, district, school, or teacher in designing his/her own curriculum. The benchmarks established a user friendly reference guide constructed from the framework of *Science of All*

Americans (AAAS, 1989) and reinforced this framework with pertinent research and teacher/administrative knowledge.

In 1996, The National Research Council, through the collaboration of the National Committee on Science Education Standards and Assessment (NCSESA) and the National Academy of Sciences (NAS), produced the *National Science Education Standards* (NRC, 1996). This work stemmed from the early AAAS work, but established a rigid standard framework. Within the writings of the standards, the NRC acknowledged the previous work provided by the AAAS and maintained its spirit.

> The National Research Council of the National Academy of Sciences gratefully acknowledges its indebtedness to the seminal work by the American Association for the Advancement of Science's Project 2061 and believes that use of the *Benchmarks for Science Literacy* (AAAS, 1993) by state framework committees, school and school-district curriculum committees, and developers of instructional and assessment materials complies fully with the spirit of the content standards. (NRC, 1996, p. 15)

Several facets of the science community are still developing material to assist the furthering of scientific literacy. Project 2061 is continuing its three phase goal through the development of educational works such as *Blueprints for Reform* (AAAS, 1998) and *Atlas of Science Literacy, I and II* (AAAS, 2001; 2007). The NRC has also published multitudes of reference material to assist all levels of education through materials like *Educating Teachers of Science, Mathematics and Technology* (NRC, 2001), *Investing the Influence of Standards* (NRC, 2002), and *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics* (Fox & Hackerman, 2003).

Like the mathematics standards, the science community is striding forward in the progression of their national standards and associated materials. Unlike the mathematics community, science is making this transition structuring its content directly with other associated subjects, mathematics and technology, specifically. “Coordination of science and mathematics programs provides an opportunity to advance instruction in science beyond the purely descriptive” (NRC, 1996, p. 214). Certain science standards have been designated specifically to address the need for technology, “these standards emphasize abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology” (p. 106). Science has established an interdisciplinary approach to all its related fields of study while constructing its own position, a beneficial characteristic when considering STEM education. This alignment allows science and its standards to be more appealing and flexible when considering subject integration across the realm of education.

Standards for Technology Education

Technology education did not exist as a field of study until 1985, only two years after the *A Nation at Risk* (NCEE, 1983) report was issued and approximately at the same time science and mathematic organizations were commencing their initial research toward their national standards. Prior to 1985, a field associated with technology education did exist, but under a variety of headings through out the history of education. These headings included but are not limited to manual arts, industrial arts, and industrial technology. However, it is the current form of technology education that we are concerned with throughout this document.

In 1996, *Technology for All Americans* (TfAA) (ITEA, 1996) was published by the International Technology Educational Association (ITEA). As previously stated in this document, the earlier established standards of mathematics and science mentioned an accessory technology base. The association between science, mathematics, and technology required the identification and standardization of technology as a subject. However, the definition of the technology required clarification as to its meaning within the whole education community (refer to Table 2).

Document	Definition
Benchmarks for Scientific Literacy	Technology "extends our abilities to change the world: to cut, shape, or put together materials; to move things form one place to another; to reach farther with out hands, voices, and senses."
National Science Education Standards	Technology is used "to make modifications in the world to meet human needs."
Standards for Technological Literacy	Technology is "the innovation, change, or medication of the natural environment in order to satisfy perceived human wants and needs."

Note: Adapted from Project 2061 (American Association for the Advancement of Science). (1993). *Benchmarks for science literacy.* New York: Oxford University Press, p. 41.
Note: Adapted from National Research Council (U.S.). (1996). *National science education standards: observe, interact, change, learn.* Washington, DC: National Academy Press, p. 24.
Note: Adapted from International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author, p. 242.

Table 2. Various Definitions of Technology

Previous attempts of subject identification are in the recent history of former technology education: i.e., industrial arts projects such as the *Industrial Arts Curriculum Project* (Lux & Ray, 1970a & b), *Technology, An Introduction* (Devore, 1980), and *The Jackson Mill's Curriculum Theory* (1979). Each of these materials had varying interpretations of the prevalent field associated with technology. The *Technology for All*

Americans Project (TfAA)(ITEA, 1996) included the trends of current and projected technological developments with societal and governmental needs. The authors also established a primitive foundation from which to construct standards. Critical to this effort was the establishment of the need for technological literacy:

> Technological literacy is much more than just knowledge about computers and their application. It involves a vision where each citizen has a degree of knowledge about the nature, behavior, power, and consequences of technology form a broad perspective. Inherently, it involves educational programs where learners become engaged in critical thinking as they design and develop products, systems, and environments to solve practical problems. (TfAA, 1996, p. 1)

Within four years of the release of the TfAA rationale, ITEA published the *Standards for Technological Literacy* (STL)(ITEA, 2000). This work presents not only the standards associated with technology education, but also aligns the appropriate benchmarks for respective portions of K-12 grades. The STL has a total of twenty academic standards that are categorized as either cognitive or process standards: much like the NCTM standards. The number of standards is staggering when compared to the ten NCTM standards and the seven NAS/NRC standards. However, each organization has its own format for the presentation of data and therefore, some variance in the assignment of a standard is inevitable.

Like the two preceding examples, the STL documentation also includes a definition of the basic role of technology in the educational system. The work is a common set of expectations for what students should be able to do in a technology enhanced learning environment. It is laid out to be developmentally appropriate for students and to promote interdisciplinary connections with other subjects. Science and mathematics are specifically addressed as critical aspects of technology education, though with varying relationships.

> Science and technology are like Siamese twins. While they have separate identities, they must remain inextricably connected in order to survive. Science provides the knowledge about the natural world that underlies most technological products today. In return, technology provides science with the tools needed to explore the world…Mathematics and technology have a similar but more distant relationship. Mathematics offers a language with which to express relationships in science and technology and provides useful analytical tools for scientists and engineers. Technological innovations such as the computer, can stimulate progress in mathematics, while mathematical inventions, such as numerical analysis theories, can lead to improved technologies. (ITEA, 2000, p. 44)

In 2003, ITEA produced a companion document to assist in the assessment of the established standards. *Advancing Excellence in Technological Literacy* (ITEA, 2003) was created to provide support for the technology standards through facilitation (AETL, 2003). Areas of interest included student assessment, professional development and program standards. In 2005, a revision to ITEA's original work, TfAA, was published with a broader scope to address a more global influence of technology education: *Technological Literacy for All* (TLfA)(ITEA, 2005). Currently, additional addendum documents have been drafted to supplement the TfAA collection and include items relating to structuring programs, assessing students, preparing teachers, and implementing backwards design (ITEA, 2005).

Standards for Engineering Education

As of today, engineering education standards do not exist. The National Academy of Engineering (NAE) began working on a project to determine the value and feasibility of creating engineering education standards. The project was slated to start in November of 2007 and progress over an eighteen month period. According to the NAE website, the project is still under review with the next scheduled meeting occurring sometime in July, 2009 (NAE, 2009). Thus far we have examined the historical process of three academic subject standards. It was necessary to explore these histories in order to understand the transitions that have occurred that would eventually lead to the foundation of STEM and STEM education. Through such understanding, a better explanation of how each of these subjects interrelates as indicated by their standards may be attempted.

Interrelationships

Upon reviewing the mathematics, science, and technology standards documentation, several interrelationships are easily identifiable, if not clearly stated within the text. The standards in each subject may be correlated to varying degrees, depending upon associated benchmarks, grade level, and proposed cognition. This interrelationship can be further reinforced by the shared goal of student literacy in each subject. Literacy, by definition, is "the quality or state of being literate" (Merriam-Webster, 2000, p. 679). To be literate, a person must be: "able to read and write, versed in literature or creative writing, or [based upon our subjects of interest] has knowledge or competence in a subject or area; i.e., an educated person" (Merriam-Webster, p. 679).

Scientific literacy implies the "knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It also includes specific types of abilities" (NRC, 1996, p. 22). More concisely technological literacy is comprised of the "ability to use, manage, assess, and understand technology" (ITEA, 2000, p. 9). The NCTM documentation did not present a clear definition regarding literacy, but similar implications towards the establishment of mathematical concepts, principles and abilities were suggested within the documentation (NCTM, 2000). It is from these self-defined attributes of literacy, in addition to the documentation from which they were obtained, that a clearly connected expectation exists; an expectation that would become the basis for STEM and STEM education.

The most influential of these interrelationships may be observed during the actual applications of each collection of standards in an educational setting. Several STEM-like programs have been attempted throughout the history of these three academic subjects, only recently being aligned with prescribed national standards. Each presents a unique approach to the interpretation of STEM education, varying in application and expected outcome while still aligning with the implications of each of the academic subjects involved.

STEM Applications

The following is a brief collection of STEM applications currently in use. Each of these programs presents a varied interpretation of STEM and the application of STEM education. Required materials and costs for each application will be discussed in addition to any documented research and/or evaluations that were available during the time of the study.

Integrated Math, Science, and Technology – IMaST

In 1991, Illinois State University assembled three professors within the college of education to establish a new organization on the campus. This organization would represent the collective interest of mathematics, science, and technology education, subjects in which each of the professors were renowned. This new organization would become the *Center for Mathematics, Science, and Technology (CeMaST)*. It was the task of this center to develop new instructional material that would combine the collective benefits of all three subjects in order to enrich student learning. By 1992, the appropriate funding was awarded by the National Science Foundation (NSF) and the Integrated Math, Science, and Technology (IMaST) curriculum project was born.

IMaST is a middle school-based program adapted to sixth, seventh, and eighth-grade level students. Each of the 16 modules is based in a constructivist learning environment. In this learning environment the students become active members of learning/instruction through inter-student collaboration and activity based problem-solving activities. The problem-solving activities are arranged via the DAPIC model. The DAPIC acronym stands for define, assess, plan, implement, and communicate. As students work to explore and solve the situations and problems presented to them in the learning cycle activities, they develop strong critical thinking skills such as predicting, hypothesizing, planning, controlling variables, analyzing, interpreting, and assessing (CeMaST, 2008). This is not necessarily an ordered or sequential model. In fact, it was purposefully developed to be variable, like that of student learning. The importance of this model lies in the teacher observation and the student identification of each of these elements during a given project. The IMaST (CeMaST, 2008) instructional approach recommended to aid the attainment of integrated learning is as follows:

> *The Challenge*. An integrated activity that introduces the overall module objectives and key concepts followed by a series of mathematics, science, and technology activities set in a learning cycle.

> *The Learning Cycle*. A four-phase instructional model having the following components: Exploring, Getting the Idea, Applying the Idea, and Expanding the Idea. The function of this cycle is to guide both the teacher and student through the modules intended content in an effortless and seemingly natural progression. The hopeful product is a productive learning experience.
>
> *Making Connections*. This section allows students to use their personal experience to develop their own knowledge; typically placed at the end of the activity. These readings help students to expand and link what they are learning to personal real-world situations.
>
> *Concepts in Context*. This section helps students connect what they are learning to a broader context beyond the classroom. These readings focus upon the impacts science and technology may have regarding societal and environmental implications. Upon completion of each module, an integrated assessment is used to measure the students' performance and ability.(CeMaST, 2008, IMaST Overview)

The *Student Assessment* is comprised to two main sections: *Activity Assessment* and *End-of-Module Assessment*. The Activity Assessment is outlined in the teacher's edition of the textbook and follows each activity in the module. The assessment is rubric based and is used to measure the problem-solving abilities of the students regarding both content and process skills. The End-of-Module Assessment is comprised of five individual sections of measurement: Group process activity, portfolio assessment, DAPIC self-assessment, DAPIC assessment (teacher), and team growth rubric. The concept behind the multiple rubrics and writing-based assessments is to provide the teacher with the broadest view of the students' achievement of the information and associated skills.

The IMaST program was developed by and intended for true inter-disciplinary applications, like team-teaching. However, in the majority of public schools, team-teaching is not always a viable option due to either an insufficient number of capable teachers or the lack school funding. Therefore, the IMaST program was designed in such a way that is could still be implemented by a single teacher in any of the three subjects of mathematics, science, and/or technology. Each module comes in a teacher textbook, complete with assessments, equipment and material lists that may be modified per the teachers' specifications. The modules are categorized per grade level.

Required Materials and Cost – IMaST

The curriculum, in its current rendition, consists of 16 modules. Each module is in textbook form and is available in both teacher and student editions. The student textbooks are currently available for $15.95 per module, while the teacher editions are slightly more expensive, $19.95 per module (RonJon, 2008). Package deals were not found to be available through the publisher, RonJon Publishing Inc.

Research and Evaluation – IMaST

Current research on the IMaST material has been limited to NSF evaluation of the funded material. Studies conducted by the assigned external evaluators have been favorable. During the development of the sixth-grade modules student learning outcomes were assessed with the mathematics and science sub-tests of the TerraNova Multiple Assessments (RonJon, 2008, IMaST/Test results). TerraNova assessments are created and distributed by the CTB McGraw-Hill publishing company. Each assessment "combines selected-response items with constructed-response items that allow students to produce short and extended responses" (CTB McGraw-Hill, 2008, Detail page).

Pre and post-tests were administered to both IMaST students and a demographically similar comparison group. Students exposed to the IMaST program performed slightly higher in mathematics (F = .08, adjusted mean = 62.33) but it was not statistically significant when compared to the controlled student group: adjusted mean =

61.01. Results from the science sub-test indicated that the IMaST students preformed at a higher level and scores were statistically significant (F = 13.22, p = .0003, adjusted mean = 64.85) when compared to the scores of the controlled student group: adjusted mean = 61.30 (RonJon, 2008, IMaST/Test results).

A variation of the Trends in International Mathematics and Science Study (TIMSS) test was used for the seventh and eighth-grade levels. This test was used to compare the performance of IMaST students with a demographically similar comparison group from the same schools. Over 1000 students represented the eighth-grade sample for both the pre and post test while only 400 students represented the seventh-grade sample. Student scores from two individual subject categories: *procedures* and *problem solving* for mathematics and *knowing* and *process* for science. Math and science scores for the IMaST students' overall TIMSS scores for both mathematics and science were statistically significant (math = 37.07, science = 39.47) when compared to the non-IMaST students' scores (math = 34.10, science = 34.35) at the seventh-grade level (RonJon, 2008, IMaST/Test results). In fact, the seventh-grade IMaST students scores were statistically significant at all measured categories of the TIMSS with the exception of the *knowing* category within the science measure: IMaST = 21.18; non-IMaST = 20.07).

At the eighth-grade level, both IMaST mathematics categories scores – *problem solving* = 13.35, *procedures* = 17.72 – were statistically significant when compared to the non-IMaST mathematics categories scores: *problems solving* = 12.28, *procedures* = 16.32. However, the overall mathematics score was not significant for the IMaST scores.

The IMaST science scores were also statistically significant for both the *process* category (18.09) and the overall TIMSS scores (35.4) when compared to the non-IMaST scores – *process* = 15.83 – and overall TIMSS: 32.22. This was not the case for the knowing category, like the seventh-grade test scores, the IMaST score was not statistically significant: IMaST = 17.31, non-IMaST = 16.39 (RonJon, 2008, IMaST/Test results).

Overall, students displayed the greatest achievement gap in the mathematic *problem-solving* and science *processes* categories were noted as displaying the greatest achievement gap between the groups with the IMaST students performing at a higher level of ability. These differences were consistent for both the seventh and eighth-grade levels. ‘The external evaluator's analysis concluded that the IMaST students tend to score significantly higher in both math and science than the non-IMaST students” (RonJon, 2008, IMaST/Test results). Like the sixth-grade evaluation, science performance had greater attainment than overall mathematic ability. Teachers and students indicated “that this integrated math, science, and technology curriculum is effective” (RonJon, 2008, IMaST/Test results). The teachers rated integration as one of the most positive attributes of the curriculum. Some seemed pleasantly surprised at the impact it had on student behavior and learning.

Project Lead the Way – PLTW

Project lead the way (PLTW) is one of the more popular pre-engineering educational programs in the country. The company began its foray into education in the mid 1980s out of Clifton, NY. In its brief twelve year history of classroom application – first implemented in 1996 – it has expanded from twelve New York based high schools to its current enrollment of over 2,200 schools, consisting of both high and middle schools in all fifty states. The focus of the program is to enhance pre-engineering interest and skills throughout the levels of secondary education. The anticipated product of this venture is increased enrollment in collegiate engineering programs as suggested in their mission statement:

> Project Lead The Way seeks to create dynamic partnerships with our nation's schools to prepare an increasing and more diverse group of students to be successful in engineering and engineering technology programs. (PLTW, 2008, Main page)

The PLTW programs align themselves with the national mathematic, science, and technology standards (PLTW, 2008). From their list of goals, the program claims to offer equal and non-biased educational material while attempting to decrease the collegiate attrition rate in engineering and related technology programs. It proposes to achieve this goal by building career-based aptitudes in a student’s high school experience. The philosophy clearly states that PLTW courses “offer a complete career/technical concentration with an emphasis on both mathematics and science” (PLTW, 2008, Mission Statement).

The PLTW programs are specific to middle or high school development. The middle school program, *Gateway to Technology*, consists of five possible units designed for sixth-grade through eight grade implementation. The high school program is comprised to two specific curriculums, *Pathway to Engineering* and *Biomedical Sciences*. Both programs are designed to align with the typical four-year high school experience. The only prerequisite for either of the high school curriculums is enrollment in college preparatory mathematics and science courses.

The *Pathway to Engineering* curriculum is divided into three sections of available courses: foundation, specialization and capstone courses. The foundation courses introduce a student to the introductory concepts of engineering and electronics. After achieving some of the base problem solving and associated skills base, the student may transition to the specialization courses. At this juncture, students choose an area to focus their engineering development upon and continue to study that area. Lastly, the capstone section allows an independent study of engineering through a cohort of students sharing similar interests.

The *Biomedical Sciences* curriculum is still under initial development. It is currently being tested in selected schools prior to public release and full scale educational implementation. An available item with either of the high school curriculums is college credit. The college credit is based upon the requirements set by the supporting university/college in agreement with PLTW. Currently, there are 29 universities/colleges offering college credit to PLTW students nationwide. Each of the higher education institutions are also national affiliates of PLTW and function as their respective state training facility for the program. The training is mandatory for all teachers and staff planning to use the official PLTW material.

To obtain the credit, the student must maintain at least a B average in all PLTW courses. The student must also stay above a 70% score on the college credit examinations that are supplied as part of the course. This is in addition to the required portfolio for each PLTW course as well as the $200 tuition fee (PLTW, 2009, Assessment & evaluation page).

Required Materials and Cost – PLTW

PLTW is a non-profit organization that provides educational curriculum at little if any cost to a school. However, for a school to align itself with the curriculum, a variety of equipment and software is required via a signed letter of commitment with PLTW. Also required is summer staff training for teachers and staff who will be responsible for instructing PLTW curriculum. Prices are dependent upon school investment and available equipment. PLTW also offers bundle packages for its required software that a school or district can purchase at a discount through PLTW. Depending on the needs for initial program startup, the costs can vary from a few thousand dollars to over $60,000 for a school to implement the program (refer to Figure 1).

Research and Evaluation – PLTW

The majority of data representing PLTW has been collected either by the organization itself or through a representative group or partnership. Currently, no outside group has conducted research on PLTW, its curriculum, and its influence upon student learning. The data that is reported publicly by PLTW is that of demographic data regarding its growing audience of customers and their associated demographics. PLTW also provides links to public reviews as evidence of its influence upon the community as a whole.

The Southern Regional Education Board (SREB) is the one of two organizations to conduct research on PLTW that extends beyond testimonials or demographical data. The SREB has been in partnership with PLTW since 1999. The SREB represents *High Schools that Work*. This program is a career and technical program developed for the south-eastern portion of the country involving schools from Delaware to Texas. In addition to the partnership with SREB, PLTW is sponsored by some of the following organizations: Society of Manufacturing Engineers (SME), National Aeronautics and Space Administration (NASA), National Association of State Directors of Career Technical Education Consortium (NASDCTEC), National Occupations Competency Testing Institute (NOCHTI), United States Department of Education, AutoDesk, Intel, and Rolls Royce.

The study conducted through cooperation of the SREB in 2005 reports a statistically significant advantage to students involved in PLTW material based upon an assessment from the National Assessment of Educational Progress (NAEP). PLTW students (n = 274) were matched – based upon their demographic information – to two groups of students from within the SREB's *High Schools that Work* program: n = 274 for each group. This program includes PLTW in addition to more traditional career and technical (CTE) studies. The questions posed within the study are listed in Table 3.

In response to the first question (refer to Table 3), PLTW student scores were found to be statistically significant in all correlated subjects (reading, mathematics, and science, $p \leq .05$) when compared to CTE student from similar fields – i.e., engineering focused – as based on the t-test. PLTW student scores were also found to be statistically significant in all correlated subjects when compared to CTE students from all fields as based on the t test: reading, $p \leq .001$, mathematics, $p \leq .001$, and science, $p \leq .050$.

MIDDLE SCHOOL COST ESTIMATE (BASED UPON AN EMPTY ROOM) – ITEM ANALYSIS IS NECESSARY TO DETERMINE BUDGET

Course	Computers (Includes Laptop for each Instructor)	Equipment & Supplies	Furniture	Software (MS Office, MS Bookshelf, Adobe Photoshop)	Consumables	Grand Total
Computer Lab	$21,762.00	$7,827.67	$8,539.30	$1,700.55	$630.95	**$40,460.47**
Design & Modeling	$1,344.00	$326.00	$0.00	$0.00	$0.00	**$1,670.00**
Automation & Robotics	$1,344.00	$6,008.75	$282.75	$0.00	$0.00	**$7,635.50**
GTT Basic Total:	**$24,450.00**	**$14,162.42**	**$8,822.05**	**$1,700.55**	**$630.95**	**$49,765.97**
Magic of Electrons	$1,344.00	$3,044.05	$0.00	$0.00	$153.82	**$4,541.87**
Science of Technology	$1,344.00	$2225.00	$0.00	$0.00	$147.58	**$3,716.58**
Flight & Space	$1,344.00	$2,938.46	$0.00	$0.00	$775.28	**$5,057.74**

- The above additional units may be selected and added to the GTT Basic program to expand the program offerings. This cost can be reduced if the school already has equipment and/or computers meeting or exceeding the PLTW specifications.
- Total cost for two middle school laboratories implementing GTT Basic with 26 student stations is approximately $50,000.

HIGH SCHOOL COST ESTIMATE (BASED UPON AN EMPTY ROOM) – ITEM ANALYSIS IS NECESSARY TO DETERMINE BUDGET

Course	Computers (Includes Laptop for each Instructor)	Equipment & Supplies	Furniture	Software (MS Office, MS Bookshelf, Adobe Photoshop)	Consumables	Grand Total
Computer Lab	$16,740.00	$7,827.67	$8,539.30	$1,313.30	$630.95	**$35,051.22**
FOUNDATION COURSES						
Intro to Eng. Design	$1,344.00	$669.45	$0.00	$0.00	$1,104.65	**$3,118.10**
Principles of Eng.	$1,344.00	$19,271.00	$0.00	$0.00	$309.27	**$20,924.27**
Digital Electronics	$1,344.00	$4,630.00	$0.00	$0.00	$68.75	**$6,042.75**
Foundation Course Total:	**$20,772.00**	**$32,398.12**	**$8,539.30**	**$1,313.30**	**$2,113.62**	**$65,136.34**
SPECIALIZATION COURSES						
Aerospace	$1,344.00	$13,683.61	$0.00	$0.00	$642.90	**$15,670.51**
Biotechnical	$1,344.00	$7,593.75	$0.00	$0.00	$1,061.65	**$9,999.40**
Civil / Architecture	$1,344.00	$3,064.87	$0.00	$0.00	$749.22	**$5,158.09**
Computer Integrated Manufacturing	$1,344.00	$35,884.34	$1,779.75	$0.00	$1,980.95	**$40,989.04**
Engineering Design & Development	$1,344.00	$390.00	$0.00	$2,168.25	$18.50	**$3,920.75**

- Per your School District Agreement, you are only required to implement one Specialization Course.
- High School costs are based on one lab with 20 stations. This cost can be reduced if: 1. The school already has equipment and/or computers meeting or exceeding the PLTW specifications. 2. The district implements courses over time.

Note: From Project Lead the Way. (n.d.).[1]*Calculating the cost of the PLTW program.* Retrieved January 23, 2008, from http://www.pltw.org/index.cfm

Figure 1. PLTW Cost Estimates for High School and Middle School Programs

Number	Questions
1	Do PLTW students in the HSTW network have significantly higher achievement in reading, mathematics and science on a NAEP-referenced assessment than other students in the network?
2	Are PLTW students more likely to take higher-level mathematics and science courses than other students?
3	How do PLTW students who complete four years of college-preparatory mathematics and science perform compared to PLTW students who do not complete four years of college-preparatory mathematics and science?
4	Do PLTW students experience more engaging instructional strategies in mathematics and science classes and across the curriculum?
5	Do PLTW students have a richer set of learning experiences in their career/technical courses?
6	Are PLTW students more likely than other career/technical students to plan to attend a four-year college or university?

Note. Adapted from Bottoms, G., & Anthony, K. (May, 2005). *Research brief: Project Lead the Way: A pre-engineering curriculum that works.* Atlanta, GA: Southern Regional Education Board.

Table 3. Southern Regional Education Board (SREB) Research Brief

In question two (refer to Table 3), all three sample groups were compared based upon four-year enrollment in either mathematics or science courses. PLTW students averaged 21% greater enrollment in both four-year mathematics and science courses than the two CTE groups' enrollment numbers reported. Question three (refer to Table 3) continues the theme of question two but internalizes it upon PLTW itself. Again, PLTW students who complete four-years of mathematics demonstrated statistically significant better performance when compared PLTW students who do not complete four-years of mathematics: $p \leq .001$. A similar statistical significance regarding student performance was reported concerning the science correlation ($p \leq .050$) of the same question.

In question four, the groups were surveyed as to their individual experiences based upon indicators established by the *High Schools that Work* program. Data collected showed that the program with the majority of intense or high emphasis on literacy, numeracy, and science as indicated by the students' responses was that of the PLTW program. This difference between the PLTW and CTE programs was found to be statistically significant ($p \leq .050$) based upon the chi-square test applied to the students' responses. A similar result was apparent in response to question five (refer to Table 3). Students' indicated that they had a richer set of learning experiences in their career/technical courses within the PLTW program. Again, the difference between the PLTW and CTE programs was found to be statistically significant ($p \leq .050$) based on the chi-square test conducted.

The final question in this study (refer to Table 3) reported that PLTW students have the highest anticipation of attending a four-year college than either of the two sampled CTE groups: PLTW = 58%, CTE from similar fields = 51%, and CTE all fields = 40%. PLTW also reported the lowest anticipated attendance of a two year college program than either of the two sampled CTE groups: PLTW = 14%, CTE from similar fields = 18%, and CTE all fields = 23%. Though this study provides statistical information that positively reflects the application of PLTW, based upon the specifications of the study, it would be difficult of generalize to any audience beyond the sample tested. More information about the samples would be required to consider a wider implication of these results.

Two additional studies were conducted in 2005 and 2006. Each study was performed by G. Rogers of Purdue University, Indiana. Purdue University is an active training site for all teachers seeking certification for PLTW. In both studies, Rogers examined the perceptions of the local technology education teachers in the state of Indiana as to their perceptions of pre-engineering and PLTW.

The first study (Rogers, 2005) was conducted using random samples of PLTW technology teachers (76) and non-PLTW technology teachers (76). The list of non-PLTW technology teachers was generated through the Indiana Department of Education. Rogers sent surveys to this sampled population from which he received 34 PLTW (*n* = 34) and 28 non-PLTW (*n* = 28) technology teachers' surveys that were completed (Rogers, 2005).

Rogers attempted to measure the selected teachers' perceptions of pre-engineering as defined by PLTW curriculum and project objectives. These items were placed in a four-point Likert scale with representative ranges from 4 (very effective) to 1 (no effect). No official mention of PLTW was included in the survey provided to the teachers. The results were predominately positive: "of the respondents, 69.4% (*n* = 43) indicated that pre-engineering education was a 'very valuable' component of technology education, and 25.8% of the respondents (*n* = 16) noted it was a 'somewhat valuable' component" (Rogers, 2005, p. 15).

In 2006, Rogers reported a study that only sampled PLTW certified teachers in the state of Indiana. Again, Rogers randomly selected PLTW certified teachers (76) and sent out surveys, from which 34 were returned (*n* = 34). In this survey the PLTW certified teachers were questioned as to the effectiveness of the PLTW programs in developing pre-engineering competencies. The resulting information was again predominately positive, “Indiana's PLTW teachers perceive the PLTW curriculum as being ‘effective’ to ‘very effective’ in developing pre-engineering competencies in their high school students. This positive perception was carried across all PLTW courses: IED, POE, DE, CIM, CEA, and EDD” (Rogers, 2006, p. 18).

PLTW program objectives and course outlines were used again in the construction of the survey instrument. These items were placed in a five-point Likert scale with representative ranges from 5 (very effective) to 1 (very ineffective). However, it must be stated that the examples listed upon the survey that were used to measure the effectiveness of the PLTW program are items selected from the PLTW curriculum and not from an outside pre-engineering data source or measurement.

As stated in the previous example, it would difficult to extrapolate beyond the population associated with this data due to the specificity and limitations of the research carried out. This is no way suggesting the product is of poor quality, simply that the existing research is limited.

Engineering byDesign – EbD

Engineering byDesign (EbD) is the product of the *International Technology Education Association* (ITEA). This K-12 standards-based program was created through the *Center to Advance the Teaching of Technology and Science* (CATTS), a sub-organization of the ITEA. It is an educational model that incorporates the national standards from mathematics, science and technology in an attempt to produce technological literacy. The model centers upon the creation of a problem-based learning environment with a constructivist focus: group exploration/development. The goal of the EbD program is to assist students in their development of technological literacy. The reasoning for such is in reaction to the growing technological and information based environment in which we all exist. For a student to become a responsible and informed participant of the occurrences in our modern lives, they must be technologically equipped. Otherwise, the changes that occur in their environment, society or their personal lives will remain a foreign and confusing construct (ITEA, 2008).

The program is designed to facilitate active engagement in mathematics, science and technology. The students will build upon their knowledge base while exploring aspects of creativity in a collaborative setting. The EbD program prides itself on their equal treatment of varying students when considering multiple demographics (ITEA, 2008). It is through this collective ideal that EbD seeks to improve STEM performance in American schools and assist in the development of future innovators in all fields.

A section of EbD program is the EbD network: also labeled eTIDEonline. This network consists of an online chat forum consisting of EbD teacher specialists dedicated to assist other interested teachers in their EbD development. The EbD network is also used for the collection and collaboration of action research as programs are implemented. This is an example of the continued commitment of the ITEA to making their overall goals in education actually occur. The EbD program is designed for K-12 implementation. Currently, the K-5 model program is in the final stages of revision prior to production. The K-5 models are divided into two curriculums models, K-2 and 3-5 curriculums. The middle school section (6-8 curriculums) is comprised of three curriculum models: *exploring technology, invention and innovation,* and *technological systems*. Each middle school section is designed to be conducted over an eighteen week period (ITEA, 2008).

Exploring technology is intended to build upon the K-5 curriculum that precedes the course. Its anticipated audience is the sixth-grade. In this course students explore aspects of technology to assist in establishing cognitive connections to the subject and its material. The activities are presented in both group and individual settings. Students are expose to the criteria typical of real-life technological settings dealing with elements of deign, criteria exploration, problem solving, modeling/constructing, and brainstorming (ITEA, 2008). Students must communicate their ideas as well as their thought processes when working through some of the assigned activities.

Invention and innovation continues the application of the design process by focusing the student's attention to the task of a new product, process, or system. Students will be exposed to some of the major occurrences in the history of innovation and how they have progressed to current inventions. The students will also investigate some of the impacts inventions have had on aspects of society and the environment in both positive and negative aspects. The invention and innovation program continues to support the problem-based critical thinking skills instructed in the exploring technology course.

Technological systems expose the students to a more in-depth look as to how the technological world interacts to perform tasks or solve complicated problems. The range of systems studies varies as to offer the greatest amount of variability in application as well as student retention. Systems relationships are also investigated. The focus is not limited to just their function, but also their underlying interrelationships that often go unseen.

The high school function of EbD is much more involved than middle program. Students have six sections from which to choose from: *foundations of technology, technological issues and impacts, technological design, advanced design applications, advanced technological applications,* and *engineering design* (ITEA, 2008). Unlike the middle schools programs, the high school courses extend over thirty-six weeks as opposed to eighteen weeks for the middle school courses.

The *foundations of technology* program is intended to address three proposed dimensions of technological literacy. The dimensions are listed as knowledge, ways of thinking and acting, and capabilities within the course description (ITEA, 2008).
The course is designed to open the thinking of the student to the broader concepts related to technology. The course begins with an historical connection to technological development. It continues with the connecting technology skills to other subjects related through research, engineering, and design attributes. This course is designed as an overall introduction to technology and addresses all the subjects listed within the designed world chapter of ITEA's *Standards for Technological Literacy*. The standards within that chapter include manufacturing, construction, transportation, information, energy and power, bio-technology, and medical technology (ITEA, 2008). By the conclusion of the course, the students should be familiar with the core concepts of technology.

Technological issues and impacts vary from the traditional technology course often found in high school programs. At the heart of this course is the exploration of the products that we use as participants in a technological society. The consequences of those products may vary from helpful advances to harmful side effects. It is the plan of technological issues and impacts to expose students to the natural world of technology and learn to draw their own opinions of the trade-offs associated with attempts at technological progression. In the technological design course students applied engineering, mathematics, science and technology skills to a variety of design-based applications. Students are forced to examine situations associated with their assigned tasks and, based upon their research, determine the highest quality solution to such. The course offers students a rare glimpse of the real-life applications that engineers and technologists have to face when attempting difficult design development and refinement. Key to this investigation is the students' understanding of the relationships and functions systems, both manufactured and naturally occurring.

Advanced design applications focuses upon four technology subject areas: manufacturing, construction, energy and power, and transportation (ITEA, 2008). Each subject is investigated as to it systematic function and technological interrelationships. The idea is to briefly expose each student to the core concepts of each subject, their design implications, and impacts upon surrounding environment and society. As always, science, mathematics, and engineering factors are explored to assist in the cementing of the technological concepts.

Advanced technological applications examines the remaining four technology subject areas: medical technology, biological/agricultural, information, and entertain recreation technologies (ITEA, 2008). It should be no surprise that this course matches the previous course, advance design applications, per its content. Each subject is investigated as to it systematic function and technological interrelationships. The idea is to briefly expose each student to the core concepts of each subject, their design implications, and impacts upon surrounding environment and society. As always, science, mathematics, and engineering factors are explored to assist in the cementing of the technological concepts.

In the capstone course, *engineering design*, students attempt to apply their learned skills into more complicated design processes. The students are challenged by more realistic limitations often experienced by designers or engineers. The object is to test the student to become resourceful and inventive while still obtaining a practical product that applies to the condition or objective (ITEA, 2008). The process is systematic and progressive so while the students are attempting to confront the given task, they are not overwhelmed by the project(s). The assignments are both for individual and group implementations and are assessed using a variety of methodologies.

Required Materials and Cost – EbD

The materials required for appropriate implementation are available through the ITEA's publications department. Within this department, full curriculums are available for each of the previously listed courses. The prices of these curriculums range from approximately $40 to $30 depending on the format chosen: printed text or CD. Additional discounts are available for ITEA members.

In addition to the course curriculums, supplemental materials that align with the EbD program are also available. These materials range from individual lessons to exploratory content sections that go beyond the scope of the original EbD curriculum. These varied materials also range in price starting at the low-end cost of $12 for lessons and up to $90 for packages. Beyond the document itself, no other material or equipment is specifically called for to implement the EbD program.

Research and Evaluation – EbD

At the time of this research study, publically reported research for EbD was not located during the processing of the review.

The Gary and Jerri-Ann Jacobs High Tech High – HTH

In 2000, a new charter school was launched in San Diego, California. This high school – The Gary and Jerri-Ann Jacobs High Tech High (HTH) – was the product of collaboration between local business leaders and educators. The concept was to "combat the twin problems of student disengagement and low academic achievement" (HTH, 2008, About High Tech High). Based upon the findings of the *New Urban High School Project (NUHS),* 1996-1999, three foundational design principles were established. Each of these three principles is focused on the needs of the students in preparation for their real-world roles to follow high school. The three principles are as follows:

> *Personalization* – Each student at HTH has a staff advisor, who monitors the student's personal and academic development and serves as the point of contact for the family. Students pursue personal interests through projects. They compile and present their best work in personal digital portfolios. Students with special

> needs receive individual attention in a full inclusion model. Facilities are tailored to individual and small-group learning, including networked wireless laptops, project rooms for hands-on activities and exhibition spaces for individual work.
>
> *Adult World Connection* – HTH students experience some of their best learning outside the school walls. Juniors complete a semester-long academic internship in a local business or agency. Seniors develop substantial projects that enable them to learn while working on problems of interest and concern in the community. Earlier, in ninth and tenth-grade as well as middle school, students may "shadow" an adult through a workday, perform community service in a group project, or engage in “power lunches” with outside adults on issues of interest. The HTH facilities themselves have a distinctive high-tech "workplace" feel, with windowed seminar rooms, small-group learning and project areas, laboratories equipped with the latest technology, ubiquitous wireless laptop access, and common areas where artwork and prototypes are displayed.
>
> *Common Intellectual Mission* – High Tech High makes no distinction between "college prep" and "technical" education; the program qualifies all students for college and success in the world of work. Enrollment is non-selective, and there is no tracking at HTH. The curriculum is rigorous, providing the foundation for entry and success at the University of California and elsewhere. Assessment is performance-based: all students develop projects, solve problems, and present findings to community panels. All students are required to complete an academic internship, a substantial senior project, and a personal digital portfolio. Teacher teams have ample planning time to devise integrated projects, common rubrics for assessment, and common rituals by which all students demonstrate their learning and progress toward graduation. (HTH, 2008, Design principles page)

It is upon these base principles that the HTH, and its educational systems, continue to grow. Since the first school was opened in 2000, the HTH community has expanded to now include five high schools, two middle schools, and one elementary school. The HTH mission is to “to develop and support innovative public schools where all students develop the academic, workplace, and citizenship skills for postsecondary success” (HTH, 2008, About High Tech High). Each school is created from the ground up in what the HTH community labels as a “bricklaying” process of development (HTH, 2008). Each progression in their system is directly reflective and inspired by the staff they employ, students they teach, and the successes of their program to date. The program, though developed from the ground up, is not rigid in its design.

The program is flexible and shapeable to both the needs of the school and the individual student. Student goals include – but are not limited to – serving a student body that mirrors diversity of the local community; integrate technical and academic education to prepare students for post-secondary education; increase the number of educationally disadvantaged students in successful secondary and post-secondary math and engineering; graduate students who will be good citizens (HTH, 2008, About High Tech High).

The HTH program relies upon "five basic strategies" to include and aid all participants of their system: *enact, inspire, enable, develop,* and *influence*. *Enact* addresses the need for the HTH program in general, including all grades levels. Currently HTH is attempting to expand its HTH program throughout the state of California beyond the reaches of San Diego. *Inspire* is the aim of having others observe and experience the HTH program. HTH is an open program, welcoming approximately a thousand curious visitors a year. *Enable* allows for other driven individuals and organizations to attempt their own HTH program. "HTH has modeled itself as an 'open source' organization, offering institutes, residencies, and a free web-based resource center for educators" (HTH, 2008, About High Tech High). *Develop* intends to aid others with professional skilled in the HTH program. HTH's Teacher Credentialing Program, in addition its Master's of Education program, allows interested staff and teachers to become fully educated and licensed in the attributes of HTH education. This includes current and future staff of the HTH itself. The persons employed by the program are required to have a shared vision to "to prepare all students for entry into the world of work and citizenship in a democratic society" (HTH, 2008, About High Tech High). Finally, *influence* addresses the need for administrative and political entities to become educated and responsive to the ideas and advantages offered by such educational practices. With such, educational policy may be adjusted to aid in the further development of institutions like HTH in varying locations without the battling of stringent limitations.

To counter such limitations, HTH has displayed a strong desire to become a self-sustaining educational entity. The system currently is funded by outside sources – approximately $23 billion per year (HTH, 2008) – however, it is currently attempting to secure ownership of each of its schools and their associated properties, thereby, eliminating reliance upon grants and donations: approximately $57 billion in real estate holdings. The goal for the HTH program is to attain a "stable platform from which to take stock of our efforts and assess our options for the future" (HTH, 2008, About High Tech High).

Upon reviewing the expansive web-based media provided by the HTH, it appears the program of study is a heavily project-based, involving the collaboration of several professionals from the fields of mathematics, science, engineering, art, and other varying subject matters. If students are absent or miss extend periods of class attendance, they are required to enroll in an independent study. The programs enacted at the HTH are variable and appear to change per year. The following are examples of some of the projects students at the HTH are experiencing.

First is an exploration in biotechnology through forensic applications. The concept of this project is to allow students to develop methods of meat and fur identification through the use of "DNA isolation, amplification, sequencing and alignment techniques" (HTH, 2008, Projects). It is a collaborative effort with HTH, City of San Diego, the Center for Reproduction of Endangered Species, and the San Diego Zoological Society. This project may even allow students the opportunity to travel to the University of Nigeria in Yola to continue the application aspect of their study.

Second is an exploration of basic physics. Pool Hall Junkies takes the game of pool back into the classroom. Students examine how the pool tables, in addition to the game itself, apply impulse, momentum, energy, and angles to work, and win. At the conclusion, students construct their own pool table, complete with sticks and cues. They must also design their own ball return system applying the principles they have learned.

Finally, an ongoing, multi-class research project dealing directly with the San Diego Bay. "High Tech High is located in the ongoing redevelopment of Liberty Station, the former Naval Training Center in San Diego, within 200 meters of San Diego Bay" (HTH, 2008, Programs). From this local setting, students can easily perform research on the bay regarding all maters of possible influence, both positive and negative. Currently two field guides have been produced to aid the local community as well as professional organizations to accomplish the city's redevelopment efforts.

Research and Evaluation – HTH

Currently, specific research has not been performed on the HTH program, but within their documentation is public notification of some achievements: 100% college admittance – 80% of which is attending a four year institution; 35% of HTH graduates are first-generation college students; greater than 30% of graduates enter math or science fields; among highest academic performance in the state of California; and Explorer Elementary program recipient of California Distinguished School Award. No references are provided from the HTH as to the sources or methods of determining some the preceding data.

Summary of STEM Applications

As demonstrated by the selected variety of STEM-based programs and applications, no precise implication for STEM education exists. The definition for STEM is simple – as previously stated – and standards for each of the subjects exist in well-structured formats. However, individual interpretation is left up to the organizations and institutions willing to invest in such efforts. These efforts should be reinforced with proper documentation along with national standards alignments of STEM subjects. This may be both a strength and weakness for STEM and STEM education. Freedom of interpretation allows for greater investigation into learning and educational settings that may aid student development in STEM subjects. On the other hand, this exact freedom without proper assessment and/or review may lead to false pretenses of STEM development. The following exploration addresses such a concern as provided by organizations and industries that not only stand to benefit from increased STEM development, but are also vital investors in such ventures.

The Demand for STEM

In 2004, the Education Commission of the States (ECS) produced the report *No Time to Waste: The Vital Role of College and University Leaders in Improving Science and Mathematics Education*. It was the culmination of a meeting held between the U.S. Secretary of Education and a collection of presidents of higher education institutions (ECS, 2004). The report highlights collections of research conducted regarding the state of science and mathematics in schools. These reports include student and teacher performance in addition to international comparisons.

Of specific interest in this report are the estimations made in reference to the current status of STEM in America and other countries. According to the report, the American STEM workforce has quadrupled over the last twenty years. Conversely, the number of students preparing for careers in STEM has been either stagnant or declining (NSB, 2004). An interesting correlation is noted in the ECS report that addresses this condition:

> [C]lassroom access to computers and the internet had expanded significantly, as has the availability of Advanced Placement science and mathematics courses. Nearly all states have established academic standards in both science and mathematics, and the annual testing of students in core subjects mandated by the No Child Left Behind Act will be extended, in the 2007–08 school year, to include science. Still, on a number of key indicators, America's systems of science and mathematics education continues to perform below par. (ECS, 2004, p. 3)

The issues observed here were utilized to invoke recommendations for the benefit of institutions of higher education. The recommendations centered upon the preparation of future teachers to address the implicated short comings found in the STEM proficiencies.

The recommendations consisted of an increased preparation of science and mathematics abilities for future teachers in addition to greater collaboration with industry (ECS, 2004).

In 2005, The Business-Higher Education Forum (BHEF) created a four-part action plan to address the need for STEM improvement. The BHEF declared that the dilemma of waning mathematics and science abilities had to do with the lack of structure among the states regarding the interpretation and application of STEM-related standards. It was recommended that an overall change in educational planning would be required.

> For America to improve overall mathematics and science achievement and to increase the base of students who have taken the right course and have met standards grade by grade, it must do nothing less than implement a plan that guarantees sweeping and coordinated changes in entire educational systems. (BHEF, 2005, p. 11)

The recommendations by the BHEF were more encompassing than the previous ECS model that primarily focused on higher education's role in the STEM development equation. The BHEF four-part system is displayed in Table 4.

Part	Action
1	Establish a P-16 education council in each state.
2	Simultaneously address and align the five P-12 system components.
3	Engage business and higher education in more effective P-12 reform roles.
4	Implement coordinated national and state specific public information programs.

Note. Adapted from Business-Higher Education Forum (January, 2005). *A commitment to America's future: Responding to the crisis in mathematics and science education.* Washington, DC.

Table 4. BHEF Four-Part Action Plan

Each part of this plan requires greater involvement from local business and industries into the development of state educational reform. Action one calls for councils to be established in each state. These councils will consist of teachers and administrators from around the state. Community college and university staff are also expected to be members of this council. The councils are to produce, per state, P-16 plans consisting of a singular vision and associated evaluations for science and mathematics proficiencies.

The second part addresses five P-16 system components identified by BHEF. These systems cover statewide coordination of standards (1), curriculum (2), assessments (3), and professional development (4) (BHEF, 2005). The final part relates to the revision schedule (5) administered as needed by the council. In the third part we are once again presented with the integration of business and industry as key components of the plan. It is proposed that involving businesses with the educational reform will assist both the schools and the companies in developing the overall wealth of the state (BHEF, 2005). No research accompanies the proposed advantages of the public business support in education throughout the article.

Part four outlines the national and state process of delivering the BHEF message. This outline describes the methods suggested by the forum to build support for their action plan. The two tiers indicated – state and national – provide information to the public to reinforce the need for science and mathematics development. The overall recommendations of action and support from the BHEF are again echoed in another 2005 report, *Tapping America's Potential*. This report is a summary of the concerns for variety of local professional organizations: AeA, BHEF, Business Roundtable, National Defense Industrial Association, TechNet, etc. Suggested 'warnings' from this report are listed in Table 5.

The warnings in Table 5 were collective concerns as indicated by the organizations involved in the creation of the document. Their collaborative work produced four challenges that must be addressed to overcome the STEM deficiencies (see Table 6). A shared concern by government and industrial organizations is evident by the collection of publications. A second observation should be that few of these reports have been created with educational institutions or by their associated organizations. Private business and industrial representatives are attempting to have an influence upon educational reform.

Issue	Reasoning
Foreign competition	China not only graduates four times as many engineers as the United States, but it also offers lucrative tax breaks to attract companies to conduct research and development (R&D) in the country.
Interest in engineering	Out of the 1.1 million high school seniors in the United States who took a college entrance exam in 2002, just under six percent indicated plans to pursue a degree in engineering - nearly a 33 percent decrease in interest from the previous decade.
Student achievement	On a recent international assessment of 15-year-olds math problem-solving skills, the United States had the smallest percentage of top performers and the largest percentage of low performers compared to the other participating developed countries. This is not surprising when nearly 70 percent of middle school students are assigned to teachers who have neither a major nor certification in mathematics.
Investment in basic research	In the United States, since 1970, funding for basic research in the physical sciences has declined by half (from 0.093 percent to 0.046 percent) as a percentage of the gross domestic product (GDP).

Note. Adapted from Business Roundtable (July, 2005). *Tapping America's potential: The education for innovation initiative*. Washington, DC: Business Roundtable.

Table 5. Tapping America's Potential – The Education for Innovation Initiative: The Warning Signs

This condition is not necessarily bad; industry has been an established part of educational history since formal instruction was first identified. The observation just reinforces the level of concern existent in American industry. The American Electronics Association (AeA) demonstrated their concern in the following statement:

> America needs to recognize that future innovation in not predetermined to occur in the United States. Even if we were doing everything right, we still face unprecedented competition from abroad. (AeA, 2005, p. 3)

In 2006, Parametric Technology Corporation, PTC, in cooperation with MIT, produced the document *Preparing for the Perfect Storm* published by the National Academy of Engineering.

Challenge	Reasoning
Depletion of the teacher talent pool by the private sector	College graduates who major in math and science can earn far more as private sector employees than as teachers. Higher-aptitude students also find performance based compensation in the private sector more appealing than the traditional teacher salary schedule based on years of experience and degrees.
Cyclical employment trends	Labor supply in these fields is particularly sensitive to changes in the economy. Growth and decline in the number of annual majors in science and engineering closely track with hiring and layoff cycles; the supply of graduates typically lags behind the pace of economic recovery. To counter the impact of these trends on students' choices of majors, high school and college students need better information about the wide range of opportunities that science, technology, engineering and math degrees open up to them.
Government security needs	U.S. government agencies and firms that handle sensitive national security research and development must hire qualified American citizens, a requirement that presents a further demand for domestic talent.
Baby boom retirement	More than 50 percent of the current science and engineering workforce is approaching retirement. It must be replaced by a larger pool of new talent from a more diverse population.

Note. Adapted from Business Roundtable (July, 2005). *Tapping America's potential: The education for innovation initiative.* Washington, DC: Business Roundtable.

Table 6. Tapping America's Potential – The Education for Innovation Initiative: STEM Challenges

Unlike previous documentation, this consortium involved a large education representation: 80 education and STEM related organizations. The objective of this meeting was to discuss the concerns related to the declining STEM field professionals. An issue of note that differed from previous documents is that the average age of an employed engineer or technologist is over 50 years of age. This reality affects university programs and major industries, including governmental defense/research agencies. The formal recommendations from this meeting are listed in Table 7.

The consortium again reinforces the earlier works by the AeA, BHEF, ECS, and the Business Roundtable. The difference is in the format that PTC and MIT took in establishing this meeting. Educational representation was strongly represented in addition to interested industrial entities. PTC's involvement is equally influential due to their investment in the production of educational software and curriculum material along with their established corporate products (PTC, 2008).

PTC is currently investing in the production of new educational products in cooperation with Battelle. Battelle is an "international science and technology enterprise that explores emerging areas of science, develops and commercializes technology, and manages laboratories for customers" (Battelle, 2008, home page). Battelle is developing its own industry-driven open source curriculum. By using PTC educational curriculum as its model, Battelle will provide teacher/industry training to assist in keeping certified PTC programs aligned with current STEM transitions as they are occurring in industry.

The following findings and recommendations emerged as a result of these meetings	
1	An over arching STEM framework is needed to map standards, programs, and curricula at the K–12 and undergraduate levels to critical skill needs.
2	A strong focus on design, a core part of engineering, must become integrated into academic instruction at the K–12 and undergraduate levels. Learning design is a means by which students can learn innovation. It is also a motivator that uses discovery, exploration, and problem-solving.
3	Global engineering approaches, being used by business and government professionals, must be integrated into academic preparation at the K–12 and undergraduate levels. Students need to learn how to work collaboratively in geographically distributed teams to prepare for their roles in a global economy.
4	Employers want technicians and engineers with excellent academic preparation and 7–10 years of real-world experience. Providing real-world opportunities for K–12 and undergraduate students could cut workforce preparation time by a decade.
5	While it is important for all students to be technologically “literate,” for the United States to succeed in a highly competitive global economy, we should aim to have all students become technologically “fluent.”
6	Rigorous research-based approaches to teaching and learning should be the foundation of K-12 and undergraduate T&E programs.
7	Traditionally underrepresented groups, including women and minorities must be engaged and recruited into T&E jobs to have enough people to meet the workforce needs, to spark creativity and innovation through diverse perspectives and approaches to problem-solving, and to communicate and connect with various partners, clients, and members of the supply chain in a global economy. Programs should be designed to involve these populations.
8	Assessments and certifications are needed to create a baseline and to benchmark achievements toward our national STEM workforce goals.

Note. Adapted from PTC-MIT Consortium. (2006). *Preparing for the perfect storm*. Washington, DC: National Academy of Engineering.

Table 7. PTC-MIT Consortium Recommendations

The preceding collection of STEM applications is a portion of what is currently available on the educational market. Each demonstrates an individualized approach to the integration and application of the four subjects while still striving for what appears to be similar end products. As previously stated, the ACC (2007) indicates that there are up to 105 government funded STEM education programs in the United States totaling an excess of 3.12 billion dollars. In 2005, the Government Accountability Office (GAO) identified 207 STEM education programs, each federally funded to an excess of 2.8 billon dollars (GAO, 2005). These reports differ statistically due to the varying forms of identification publically issued by each of the STEM programs. Even the two agencies, the ACC and the GAO, differed as to how they defined STEM programs in general.

To adhere to a measure of accountability, the ACC attempted to evaluate the available programs for their proposed “scientific rigor regarding measurement of impact on student outcomes” (2007, p. 26). They received a total of 115 evaluations from varying agencies. Of the 115 evaluations submitted, “10 evaluations were scientifically rigorous evaluations that produced preliminary findings about a program or project’s impact on education outcomes...only four of the 10 evaluations were found to posses a meaningful positive impact. Fifteen were scientifically rigorous impact evaluations that are currently under way and have yet to report results. Sixty-five fell into the third level of the hierarchy…they were less rigorous evaluations of program or project impact. Twenty-five were not impact evaluations…they did not seek to measure a program or project’s impact on education outcomes” (ACC, 2007, pp. 26-27).

The lack of both number and quality of program evaluations is more than discouraging. Given the large financial investment by both federal and private institutions, as well as the numerous annual reports begging for STEM workforce improvement, it is surprising that more evaluation initiative has not occurred.

As previously stated, NSF is modifying its own evaluation procedures to help curb this condition. However, that still leaves more than 70% of federal investments unaccounted.

Instruments should be developed to aid this issue. By measuring the level of student attitude toward STEM in a variety of educational environments, institutions may better ascertain to what degree their programs are effective. This is the first step in helping solve a problem that seems to have existed since 1983, if not longer.

Variables of the Instrument

To develop an instrument capable of measuring student attitudes toward STEM, several existing instruments were reviewed. Many of those reviewed are very strong assessments as indicated by their reported statistics. Still, some seemed to exist only to reinforce the measurement of student achievement. One example is that of the affective instrument located on the *Trends in Mathematics and Science Study* (TIMSS). The TIMSS instrument does provide a useful factorial model that will in fact be discussed later as a useful reference (Chiu, 2007). Nevertheless, such analysis has come under fire for suffering “from a number of methodological inadequacies;” not measuring up “to those [instruments] that are now expected for these affective attributes by main stream researchers” (Fensham, 2007, p. 3).

Other instruments offered a strong basis for an instrument design, but did not easily transition to a scale to measure student attitude in multiple subjects. *The Kuder Occupational Interest Survey, Form DD* (1970), *Ohio Vocational Interest Survey* (1981), and the *Thurstone Interest Schedule* (1947) are examples of these types of instruments. All are strong instruments, but they do not address the specific nature of this study. These scales are primarily focused upon vocational and general interests. This instrument does not intend to depict what the students wish to do for a career, but rather indicate if the

STEM-based program has had an influence – positive or negative – upon the attitude of student population exposed to such education. Traditional vocation and/or interest scales were not designed to measure the four subjects of STEM and/or the students' attitudinal change.

Therefore, to construct this instrument, varied affective based documentation including associated instruments were sought and reviewed. In addition, the constructs of learning theory were also explored, giving attention to the cognitive, affective, and behavioral domains related to attitude. The following is an exploration of attitude and affective devices in an attempt to best create an instrument to indentify student attitude toward STEM-based programs.

Attitude

An abundance of definitions can be found in any document or text that attempts to grapple with attitude and attitudinal measures. "[T]he concept [attitude] has been plagued with ambiguity," so much so that researchers "may find it difficult to grasp precisely how they are conceptually similar to or different from one another" (Rokeach, 1968, p. 110). The assortment of available definitions has been both a strength and a weakness in the creation of attitudinal instruments.

> [T]he meaning of a concept is defined in terms of its relations to other constructs in a theoretical network. Thus two investigators may offer different explicit definitions of attitude. However, if their attitude theories revealed that they agreed on the relationships between attitude and other concepts…it could be argued that the term "attitude" has the same meaning for the two investigators." (Fishbein and Ajzen, 1975, p. 5)

It is for this reason that many of the definitions may be interchangeable (Rokeach, 1968). Allport defined attitude as "a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which with which it is related" (Allport, 1935, p. 810). Fishbein and Ajzen offer a similar interpretation of the concept by stating attitude is "a learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object" (1975, p. 6). Thurstone and Chave (1929) explain the concept of attitude to represent the "sum-total of a man's inclinations and feelings, prejudice or bias, preconceived notions, ideas, fears, threats, and convictions about any specific topic" (pp. 6-7). Finally, Merriam-Webster defines attitude as "a: a mental position with regard to a fact or state, b: a feeling or emotion toward a fact or state" (2000, p. 74).

Fishbein and Ajzen (1975) to be consistent across most interpretations have observed three common features of attitudinal definitions. The three common features of attitude are that attitude is (1) learned, (2) it influences action, and (3) it is consistent when in action: positive or negative (p. 6). Each of the three common features can also be identified within the varied types of definitions offered for attitudinal research: simple, multi-dimensional, and bi-dimensional. Zan and Martino provide a clear interpretation of these definition classifications in their 2007 report regarding attitudes towards mathematics. The three classifications provided on page 158 of their report are listed as they appeared in the text below.

1. A 'simple' definition of attitude, that describes it as the positive or negative degree of affect associated with a certain subject. According to this point of view the attitude toward mathematics is just a positive or negative emotional disposition toward mathematics (McLeod, 1992; Haladyna, Shaughnessy J. & Shaughnessy M., 1983).

2. A multi-dimensional definition, which recognizes three components in the attitude: emotional response, beliefs regarding the subject, behavior related to the subject. From this point of view, an individual's attitude toward mathematics is defined in a more complex way by the emotions that he/she associates with mathematics (which, however, have a positive or negative value), by the individual's beliefs toward mathematics, and how he/she behaves (Hart, 1989).

3. A bi-dimensional definition, in which behaviors do not appear explicitly (Daskalogianni & Simpson, 2000); attitude toward mathematics is therefore seen as the pattern of beliefs and emotions associated with mathematics.

Some studies do not provide a definition of attitude; relying heavily upon the implication of the applied instrument (Daskalogianni & Simpson, 2000). The variety of research and interpretations of attitude has allowed for some critics to refute the concept of attitude in scientific or social research (Doob, 1947; Blumer, 1955; Rokeach, 1968). They believe that the ambiguity of the concept would yield weak results and distract from more valuable studies. This has been especially true regarding the attempt at establishing the attitude-behavioral relationship. Wicker (1969) stated that correlation reports between attitude and behavior are “rarely above .30” and that only “10% of the variance in behavioral measures” can be explained (p. 65).

Fishbein and Ajzen (1975) agree that behavioral studies have not directly correlated with attitudinal measurements. Such results are rendering an incomplete picture of the attitudinal concept and its application (p. 341). It is believed that the majority of attitudinal findings can only obtain the affective category of a person’s attitude, thereby, omitting the cognitive and behavioral constructs. In opposition, Rokeach (1968) reports research that concludes cognition, behavior, and affect are in constant interrelation and, therefore, must be measured together; “all such theories share the common assumption that man strives to maintain consistency among the cognitive, affective, and behavioral components within a single belief [attitude]” (p. 114).

The preceding examples and lack of consistency has yielded a general consensus that “research on attitude has been judged to be particularly contradictory and confusing”

(Zan & Di Martino, 2007, p. 158). It has been proposed that the reasoning for this is due to the long standing focus upon instrument development/application rather than the reinforcement of a theoretical framework. This proposition could be one of the key factors that are creating disagreement among professionals involved with attitudinal research. An alternative approach has been to view attitudes and attitudinal measurements as “evaluative judgments, formed when needed, rather than as enduring personal dispositions” (Schwarz, 2007, p. 2). This ‘construal model’ approach corroborates the variety of interpretations and applications thus reported. However, this approach may fail at establishing stability for attitudinal measurements. Schwarz provides a wonderful explanation of this condition through the description of a judge making varied court decisions.

Schwarz (2007) states that a “person’s attitude is ‘stable’ when the person provides similar attitude reports at different times and/or in different contexts” (p. 6). This is exemplified when a judge passes similar judgment on cases that share similar attributes and conditions according to the information provided. If the context is the same, the attitude should be stable. If the context of the judgment should change – i.e., by a change in information or condition – the initial attitude demonstrated will not longer fit the model. This would require a different attitudinal framework that is constructed around the new combination of information.

> [T]he variables that determine the size of context effects are also the variables that determine the stability or change of attitude judgments over time. Hence, construal models are compatible with the observation of change as well as stability in attitude reports and specify the conditions under which each one will be observed without assuming that people “have” enduring attitudes.” (Schwarz, p. 8)

The attitude is dependent upon the variables that exist in any one given situation. Therefore, the attitude measurements and definitions should be specific to the variables and conditions for which it is to be implemented. If this is followed, then the established concept of attitude created for that situation should remain stable.

So, it is imperative for this study to establish a definition of attitude that is reflective of the variables and conditions for which it is to be implemented. As a result, a multi-dimensional attitudinal approach is intended and will be the focus of the instrument development for this study. It is believed that components of student emotions, beliefs, and behaviors would yield the most comprehensive and hopefully conclusive results regarding student attitude toward STEM. To establish these components, an alternative approach was investigated. Existing attitude instruments were reviewed; however, the basis for this instrument began by addressing the concern that existed regarding the STEM situation, not the repetition of existent measurements. It is such a concern that allowed for the following investigation.

Several attributes of attitude were taken into consideration for this study. Initially, the primary focus only involved student interest. However, after reviewing several literary works, it was concluded that focusing entirely on student interest would not appropriately reflect a student's affective domain. It was not long until the list of possible categories/components became overwhelming. The majority of available 'terms' appeared to exchange basic properties and roles depending on the interpretation of the researcher and document being reviewed. A similar condition was demonstrated within the research used to establish the identity of an attitude as previously mentioned. To counter this issue, a list of terms with a semblance of consistency; across both definitions and applications was sought.

As suggested in the first chapter, interest was first identified purely from observation and reflection of the current condition as it exists. Of course, simple, personal observation is not nearly enough to establish the grounds for a full research study. Current instruments relating to interest had to be collected and reviewed. An instrument of key notice was the *Concerns-Based Adoption Model* (CBAM). The reason for the involvement of the CBAM was the design and focus of the instrument.

This model originally concentrated on how a person, specifically a teacher, reacted to a change in instruction or educational format presented during a professional development sequence. The concept was to be able to gauge how a person reacts to a presented change over the course of its implementation. The CBAM concept was closely related to the problem that is presented to a student when engaged with a STEM-based program. Is it possible to gauge how a student may react to a new educational material and format? Does a student accept or reject the change?

Concerns-Based Adoption Model

The CBAM was born from research at the *Research and Development Center for Teacher Education* (R&DCTE) at the University of Texas at Austin during the early to mid 1970s. However, it was the earlier work from Frances Fuller in the late 1960s that laid the ground work for the development of the CBAM instrument. Fuller began by focusing upon undergraduate education majors. According to Fuller’s own writings, this was an area warranted attention.

> Teacher preparation is probably in greatest need of such information. Education courses are admittedly not regarded as the most interesting on the campus. In some quarters they are even held in contempt. They 'take' less well than educators would wish and attrition is high. In general, the opinion that many education courses are not relevant to the needs of teachers is so common in the academic community, in legislatures and among the public at large that it requires little documentation. (Fuller, 1969, p. 207)

Fuller decided to examine the "developing concerns of small groups of prospective teachers…in the hope of discovering what teachers are concerned about and whether their concerns can be conceptualized in some useful way" (Fuller, p. 208).

Fuller was able to allot time for counseling psychologists to meet with student teachers as a group once a week. During that time, the student teachers could share their feelings, thoughts, and concerns with the psychologists confidentially. This study occurred in only one school system. Only fourteen student teachers were pooled for this particular study. Table 8 provides the concerns shared during the group sessions.

Time Intervals	Topic of Concern						
Chronological order of seminars	Supervising teachers, pupils' parents & school principles	School Situation[1]	Subject matter and grading of pupils	Discipline	Seminar, research project, group members	Attitudes toward self	Pupils, pupil learning and methods
Week # 1	86*	13	53	10	66	20	54
2	40	167*	45	0	65	26	29
3	100	90	133*	0	37	46	32
4	16	80	46	128*	33	12	71
5	17	54	117	174*	16	37	78
6	17	32	82	108*	6	2	103
7	25	57	21	21	9	30	254*
8	20	28	38	0	45	97	209*
9	18	68	122*	76	10	80	31
10	24	3	58	1	10	80	160*
Week #11	19	2	9	0	19	0	186*

* The most frequent concern each week

[1] Includes school plant, facilities, rules, policies

Note: From Fuller, F. (1969). Concerns of teachers: A developmental conceptualization. *American Educational Research Journal*. *6* (2), p. 212.

Table 8. Frequencies of Student Teachers' Statements by Topic of Concern

After reviewing the collected data as well as the audio tapes collected from the interviews, it was concluded that student teachers' concerns were "a more parsimonious division than categorization by topics" (p. 211). Fuller concluded, in a broad sense, that teachers had two main areas of concern, themselves and their pupils.

The "self" concern is highlighted by the early focus on the student teachers perception of performance and discipline. As the semester continued, the student teachers' concerns shifted towards the pupils; however self-concern was still a factor, though reduced. A second study would be required due to limited generalizability of this study given the small sample size and singular location. For this study, twenty-nine student teachers from a variety of supervising pools were utilized. The group of student teachers met every two weeks and was instructed by counseling psychologists to write "what you are concerned about now" (Fuller, 1969, p. 214). The collected responses were classified into one of three categories as follows:

1. Where do I stand? How adequate am I? How do others think I'm doing?
2. Problem behavior of pupils. Class Control. Why do they do that?
3. Are pupils learning? How does what I do affect their gain?
   (Fuller, 1969, p. 214)

Results of the study are as follows:

- 22 student teachers' responses were classified under category one
- 6 student teachers' responses were expressed in both categories one and two
- 1 student teacher's response was only concerned with category two
- None of the student teachers' responses were concerned with category three
  (Fuller, 1969, p. 214)

This study confirms the dichotomous association previously collected in the first study.

Earlier conducted studies relating to teacher concerns were reviewed by Fuller after establishing this relationship. It was found that the concepts of self and pupil concerns were mirrored across all examined studies. Fuller makes special note of the consistencies found. The studies were conducted independently from each other over a 36 year span. None of the reviewed studies addressed student teacher concerns regarding required course materials and their lack of pertinent teacher preparation information. The concern felt by student teachers was also found to still exist with in-service teachers. (Erickson & Ruud, 1967; Fuller, 1969; Gabriel, 1957; Phillips, 1932; Robinson & Berry, 1965; Thompson, 1963; Travers, 1952; York, 1967)

The result of this extensive review of existing studies as well as the personally conducted studies allowed for the development of a three-phase concern model: *pre-teaching*, *early teaching*, and *late teaching*. The *pre-teaching* phase was theorized to span initial teacher contact with students during observations and student teaching up until actual on-the-job experience. Responses by teachers in this phase are typically vague; revealing little for the researchers to draw upon. It would appear that teachers at this phase are simply trying to meet the requirements of the position/school and have yet to establish a sense of identity relative to the future position.

The *early teaching* phase dealt more with teachers in their early years in an actual teaching position. On the outside, the teachers seemed to be concerned with student learning and classroom management. Conversely, confidential interviews revealed that the teachers were more concerned with the parameters of their school and how they were to function in accordance within it (Fuller, 1969, p. 220). Another concern during this phase is the teachers' concern with self-efficacy. This can be greatly affected by the teachers' relationship with supervisors, other teachers, and administration.

The final phase, *late teaching*, deals more with pupil concerns and self-evaluation. This transition moves the teacher away from concerns of peer evaluation. This proposed confidence regarding the teachers' self would then allow the teachers to become more outwardly focused, in this case, upon student learning and assessment. Little research was available regarding this specific concern within the Fuller (1969) document.

Fuller's studies would set the stage for the members of the RDCTE to develop the CBAM. The CBAM is only one interpretation of the Fuller's concern theory. Unlike Fuller, the CBAM and its researchers set out to "learn how schools might go about the process of changing" (Hord, Rutherford, Huling-Austin, & Hall, 1987, p. 4). This is a slight transition for the initial focus upon student teachers' concerns. The rationale for this shift is primarily due to the plethora of changes experienced within the educational environment. Several educational products and programs have been implemented within varying educational settings over decades since the concern theory development. Many of these programs were not successful – i.e., new math, inquiry-oriented learning – due to a cycle that Hord and company labeled the "introduction/evaluation/rejection cycle" (1987, p. 5). From the research conducted by the RDCTE, a collection of assumptions regarding change have been established. These assumptions became the foundation for the actual CBAM instrument. An itemized summary of the assumptions provided by Hord and her associates from pages 5 through 7 of their 1987 work is listed below.

Change is a process, not an event:

- It occurs over time, possibly several years
- It is not a one-day solution

Change is accomplished by individuals:
- Personal role is critical
- The individual must absorb the program completely, in order to foster change

Change is a highly personal experience:
- Every person will react differently
- Attending to differences will enhance the improvement process

Change involves developmental growth:
- Growth usually expressed in feelings and skills
- Feelings and skills tend to shift depending on degree of experience with program

Change is best understood in operational terms:
- Relate change to the actual conditions experienced by the participants
- Reduce resistance to improvement efforts

The focus of facilitation should be on individuals, innovations, and the context:
- Real meaning of change lies within the human element
- Effective facilitators work with people
- Whole school is affected
- Flexibility regarding implementation is key

These assumptions must be the central focus of the *change facilitator* (CF). The CF is a person(s) who "delivers actions based upon the needs of the individuals" (p. 9). The CF is the medium between the resource system and user system. The resource system comprises the support mechanism within the institution. All of the training, material, and general organization are provided through the resource system. The user system is comprised of the individuals who will end up implementing the innovation. The CF acts as a consultant between the supporting organization and the future users so that the transition is most beneficial to both parties. The hopeful end result is a self-sustained entity that mirrors the intentions of the resource system while being fully accepted by its users.

The CBAM model that addresses the user system is comprised of three main parts: *Stages of Concern* (SoC), *Levels of Use* (LoU), and the *Innovation Configuration* (IC) (Hall, 1974). The IC is the more recent development within the CBAM system, circa 1981. The IC "represents the patterns of innovation use that result when different teachers put innovations into operation in their classrooms" (Hall et al., 1987, p. 13). Teachers will implement each innovation in varying ways. The researchers thought it would be valuable to categorize these varying interpretations of the innovation. The end result would be an identifiable chart of "operational patterns" (p. 15). Such a device would allow the facilitator assist specific teacher concerns with the implementation of the innovation, dependant upon their current status and use. To construct a configuration, the major elements of an innovation are identified and broken into components. Added into to these components are school requirements and teacher suggestions.

Once the components are established for the school population, variations of each component are identified and grouped. Variations are the "different ways in which a teacher can put a component into operation in the classroom" (Hall et al., 1987, p. 14). The most frequent variations are identified and listed so that, again, teacher assistance with the innovation may be both quicker and appropriate. Checklists can also be constructed per the varying configurations identified. These checklists are employed as an identification tool to locate concerns of the users.

The LoU, developed in 1975, "describes behaviors of innovation users and does not at all focus on attitudinal, motivational, or other affective aspects of the user" (Hall, Loucks, Rutherford, & Newlove, 1975; Hall et al., 1987, p. 54). The LoU attempts to identify what a teacher is actually doing with the innovation. Currently, there are eight LoUs. They are briefly listed in Table 9. The levels of uses are demonstrated through an interview process and observations. A chart is provided to aid the interviewer/observer in identifying the most appropriate level for the user. The information obtained from this device is vital to the outcome of the innovation as well as the facilitator.

Level	Level description
Level 0 Non-Use	State in which the individual has little or no knowledge of the innovation, no involvement with it, and is doing nothing toward becoming involved
Level I Orientation	State in which the individual has acquired or is acquiring information about the innovation and/or has explored its value orientation and what it will require.
Level II Preparation	State in which the user is preparing for first use of the innovation.
Level III Mechanical Use	State in which the user focuses most effort on the short-term, day to day use of the innovation with little time for reflection. Changes in use are made more to meet user needs than needs of students and others. The user is primarily engaged in an attempt to mater tasks required to use the innovation. These attempts often result in disjointed and superficial use.
Level IVa Routine	Use of the innovation is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improve innovation use or its consequences.
Level IVb Refinement	State in which the user varies the use of the innovation to increase the impact on clients within their immediate sphere of influence. Variations in use are based on knowledge of both short and long-term consequences for clients.
Level V Integration	State in which the user is combining own efforts to use the innovation with related activities of colleagues to achieve a collective impact on clients within their common sphere of influence.
Level VI Renewal	State in which the user re-evaluates the quality of use of the innovation, seeks major modifications of, or alternatives to, present innovation to achieve increased impact on clients, examines new developments in the field, and explores new goals for self and the organization.

Note. Adapted from Hord, S. M., Rutherford, W. L., Huling-Austin, L., & Hall, G. E. (1987). *Taking charge of change*. Alexandria, VA: Association for Supervision and Curriculum Development, p. 55.

Table 9. Concerns-Based Adoption Model – Levels of Use

Neither the LoU nor the IC identify with or aid in the development of an instrument to measure student attitude toward STEM. It is for this reason that both of these portions of the CBAM system will be omitted. However, the earliest part of the CBAM to be developed – circa 1973 – holds a vital foundation from which an instrument appropriate for the study may be set. The SoC "focuses on the concerns of individuals involved in change" (Hall, 1987, p. 30). Students exposed to STEM-based programs are experiencing a change, both in educational format and expected product. Concerns in this example are referred to as "feelings, thoughts, and reactions individuals have about a new program or innovation that touches their lives" (p. 30). This explanation of what a concern is shares very similar characteristics of the attitude definitions offered earlier.

Seven SoCs make up the current application of the CBAM. These seven stages can be divided among three dimensions: *self, task,* and *impact*. An abbreviate representation of the SoC is represented in Table 10. Table 10 displays two editions of the SoC; 1974 and 1987. This was done so purposely to illuminate the differences, similarities, and progression of the SoC since it was first created in 1973. Using the SoC, facilitators apply a variety of methods to obtain concern data from the teachers. The following methods are applied strictly for "clinical work" and are not to be confused with "research or evaluation." (Hall, 1987, p. 34). Also, it is highly recommended that each of the methods be used often throughout the innovation process. Concerns do change and must be measured frequently so that administrators may account and respond to these conditions.

The first procedure recommended within the CBAM documentation is face-to-face conversations with the teachers experiencing the innovation (Hall et al., 1987). This informal assessment allows for the CF and the teachers to talk in a relaxed and stress-reduced environment. However, the CF must attempt to follow certain protocols. First, the CF must ask questions in an "informal, relaxed manner" (Hall et al., 1987, p. 33).

Second, the CF must try to be a “good listener” (p. 33). This means the facilitator must give the respondent time to respond without direction or coaxing.

	Stage	Stage description
SELF	Awareness (0) *Unaware (0)(1974)*	- Little concern about or involvement with the innovation is indicated - There may be interest in similar innovations or a complete absence of awareness of interest in the area.
SELF	Information (1) *Awareness (1)(1974)*	- A general awareness of the innovation and interest in learning more detail about it. - The potential adopter is likely to inquire about obvious characteristics of the innovation …e.g., expressions of general feelings toward innovation…passing interests….may include expressions of concern about possible personal conflict or threats toward self.
SELF	Personal (2) *Exploration (2)(1974)*	- Individual is uncertain about he demands of the innovation. - Indicates exploration of the roles… includes exploration of role in relation to the reward structure of the organization and exploration of potential conflicts with existing structures of personal commitment.
TASK	Management (3) *Early Trial (3)(1974)*	- Attention is focused on the processes and tasks of using the innovation. - Indicates user’s exploration of his(/her) performance. - Issues related to efficiency, organizing, managing, scheduling, and time.
IMPACT	Consequence (4) *Limited Impact (4)(1974)*	- Attention focuses on impact of the innovation on student in his/her immediate sphere of influence. - Includes performance, competencies, and changes needed to improve outcomes.
IMPACT	Collaboration (5) *Maximum Benefit (5)(1974)*	- Focus is on coordination and cooperation with others regarding use of the innovation. - Indicates user’s exploration of the total impact of the innovation in an institutional context on learners and users.
IMPACT	Refocusing (6) *Renewal (6)(1974)*	- Exploration of more universal benefits…including major changes or replacement. - Individual has definite ideas about alternatives of the innovation. - Indicates user’s exploration of new or better ways to reach the same or new goals.

Note. Adapted from Hall, G. E. (1974). *The Concerns-Based Adoption Model: A developmental conceptualization of the adoption process within educational institutions*. Austin: Research and Development Center for Teacher Education, University of Texas, pp. 22-23, Appendix B.
Note. Adapted from Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process*. SUNY series in educational leadership. Albany, NY: State University of New York Press, p. 60.

Table 10. Concerns-Based Adoption Model – Stages of Concern

Lastly, when reviewing the teacher's response, the CF must take the entire response under consideration. This is to ensure that the appropriate stage is considered for the teacher.

A second procedure that is recommended is the use of open ended statements. This process is typically applied to a group rather than an individual in what would be considered a more formal setting than the first procedure. Teachers exposed to this procedure are asked to write down their reactions when posed with an open ended question. "Respondents should be encouraged to answer in complete sentences so as to provide enough information for accurate analysis" (Hall et al., 1987, p. 33). The responses are collected and then analyzed by the facilitators. Each sentence provided – if more than one sentence is provided – should be analyzed individually (p. 33). This will prevent the respondents concerns from being lost in the whole of their work.

The *Stages of Concern Questionnaire* (SoCQ) embodies the third and final procedure for assessing concerns. This 35-item instrument was developed by Hall, George, and Rutherford in 1979 (p. 34). The data is collected in a group setting and only requires approximately 10 to 15 minutes to complete. The instrument is regarded as both reliable and valid. For example, reliability measures for the each of CBAM SoC have been calculated through a series of longitudinal and cross-sectional studies between 1972 and 1976. Reliability varied for each stage of concern: alpha coefficients of .64 to .83 (Hall, George, & Rutherford, 1986).

Additionally, the SoCQ is both versatile and thorough. The data that is collected from the instrument may be used to profile each level of intensity that a person may have regarding each SoC. If administered frequently, the collection of information would provide the facilitator with feedback regarding the innovation and its progress from the perspective of the teacher. Lastly, it maintains its strength whether it's applied to one person or a group, regardless of the number of times (Hall et al., 1987, p. 35). This is a significant feature of the SoCQ due to both the frequent assessments of a user's concerns as well as the possibly shifting concerns themselves.

The CBAM SoC research data proposes that a person – in this case a teacher – when first presented with a change focuses solely on the self. This is not to be confused with selfishness, but more, an inward reflection regarding the innovation. The *self* dimension is comprised of *awareness*, *information*, and *personal* (Hall et al., 1974, Hall et al., 1987). The *awareness* stage indentifies whether the person has either experienced and/or even identifies the existence of an innovation. The *informational* stage reinforces *awareness*, also establishes a desire for information particular to an individual's role in the process. The *personal* stage is more difficult to interpret due to their intimate attributes it "may not be expressed as openly as informational concerns" (Hall et al., 1987, p. 31). These three stages are typical during the early stages of innovation implementation, however, can reoccur throughout the process with lesser intensity.

The *task* dimension specifically deals with the stage of *management*. This concern "becomes more intense as final preparations are made for beginning use of an innovation and during the early period of use" (Hall et al., 1987, p. 31). Teachers are more focused on "how-to" issues rather than their personal concerns. Practical solutions and conceptual clarification are critical elements that lead to success and transitioning beyond this concern. Facilitators should only “attend to the immediate demands” regarding the implementation of the innovation (p. 45). Future concerns are not a primary consideration.

The final three stages are classified under the *impact* dimension. Like Fuller’s studies, the teachers have developed their concerns – with the help of the CF – beyond the *self* dimension and are now working outward. Unlike Fuller’s studies, the outward focus is not solely related to students, but rather a broader concept of the innovation beyond its simple use. The three stages that comprise this dimension are *consequence, collaboration,* and *refocusing*. When a teacher is concerned with *consequence*, they are focused upon the innovation and its influence upon their students. Areas of interest would include student expectations, assessment development and application particular to the innovation, and the addressing of diverse learning abilities.

Collaboration is the first stage where the teacher is not longer adapting to the innovation, but instead, is adapting the innovation to them. Cooperative engagement with other teachers and personnel that have experienced the innovation or are currently integrating it is a common feature during this stage. Teachers concerns are focused on sharing information and possibly refining their own experiences now that they are more comfortable with the program. Lastly, *refocusing* is the most broad and hopeful stage of the concern theory. In an educational setting, the teacher has decided to go beyond the scope of the original innovation. Results from this SoC may include teachers offering ideas for major changes in the innovation or possibly complete replacement.

The CBAM SoC provides this research study with a viable foundation from which to begin the construction of an attitudinal instrument. Each concern represents a perceived emotional intensity regarding a specific item that can be identified and accurately measured. The amount of intensity is in direct relationship to an experienced change in the user's environment. This change can come in many forms, educational program, material, equipment, or even the entire school. Also, the SoC go well beyond the simple concept of interest including overall dimensions of the self, task, and impact. Each of these dimensions and their associated stages are identified by the innovation users through personal expressions, originating from their emotions. The definitions of *attitude* that were previously provided borrow similar elements from the SoC constructs.

However, the CBAM SoC documentation is not nearly enough to base an entire attitudinal instrument upon. To accomplish this, a more thorough review of affective characteristics would be required. This would be provided by an established body of work directly associated with attitude and the entire *affective* domain: *The Taxonomy of Educational Objectives, Handbook II*.

Taxonomy of Educational Objectives

In 1948, the annual American Psychological Association Convention held in Boston, Massachusetts brought an issue of concern regarding educational research to the forefront. Many of the researchers in attendance agreed that there was a discrepancy regarding the evaluations constructed within the studies presented. A common frame of reference would be required to improve upon communication and cooperation between the diverse population of subjects and interests.

> We grew quite enthusiastic about the possibilities of several schemes for securing, at the minimum, a common terminology for describing and referring to the human behavioral characteristics we were attempting to appraise in our different school and college settings. (Krathwohl, Bloom, & Masia, 1964, p. 3)

The hopeful outcome would be a classified and ordered objective matrix. Such a scheme would allow researchers and educators to locate their assigned objectives along the matrix and thereby identify the expected products. Given this easily accessible information, assessments may be accurately constructed (Krathwohl et al., 1964).

It is from this collectively observed need that the *Taxonomy of Education Objectives* was sought. A collection of values were expected to be developed from the establishment of this work. One value was to establish a definite classification of educational objectives. Each of the objectives should be clear as well as universally applicable. "It was hoped that the statement of an objective in similar terms by different workers would make possible a definite classification of that objective and would also permit exact inferences about the kinds of behaviors expected of students" (Krathwohl et al., 1964, p. 5). A second expected value consisted of a convenient, easy to use system for creating evaluation instruments and/or test items. This would allow educators to save time by quickly determining the most suitable assessment given a specific task or subject.

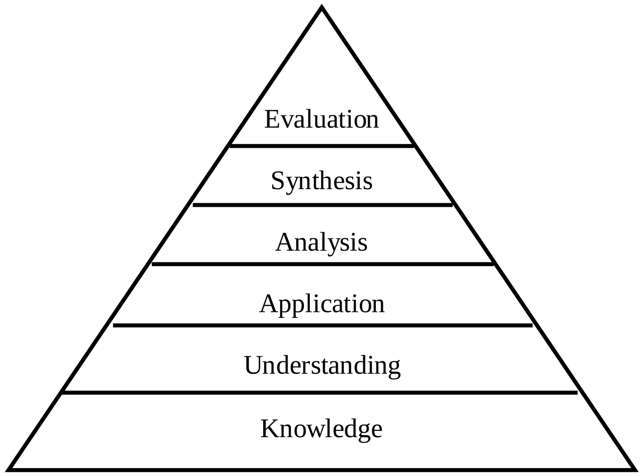
A third value would be the possible comparisons that may be drawn from the educational programs implementing the scheme. Research results from assigned classifications and comparisons could yield imperative information for the overall education system. Additionally, collected data may also assist in the refinement of the scheme itself. A final and plausibly most hopeful value would be to construct an optimal, ordered, and objectively defined educational model.

> If such order was confirmed by various types of observations and research findings, the order and principles of arrangement should be of value in the development of a theory of learning which would be relevant to the complex as well as simple types of human learning. (Krathwohl et al., 1964, p. 6)

After committing to these values, several meetings took place to establish possible domains of the proposed taxonomy. "We found that most of the objectives stated by teachers in our own institutions, as well as those found in the literature, could be placed rather easily in one of three major domains or classifications" (p. 6). From this exploration, the domains of educational objectives that were identified are *cognitive, affective,* and *psychomotor* classifications.

The *Taxonomy of Educational Objectives, Handbook I* (Bloom & Krathwohl, 1956) was the initial product of the taxonomy initiative focusing upon the *cognitive* domain. The purpose of the *cognitive* domain was to establish objectives that "emphasize remembering or reproducing something which has presumably been learned" (Krathwohl et al., 1964, p. 6). It is within this work that the famous pyramid design of the taxonomy was established and has existed ever since (refer to Figure 2). The foundation of the pyramid rests upon *knowledge*. *Knowledge* is represented by the ability to recall or recognize information, remembering (Anderson & Krathwohl, 2001).

Following *knowledge* is the next proposed level of cognition, *comprehension*. *Comprehension* is represented by the ability to understand and interpret information. Upon establishing these two foundational abilities, a learner can then transcend to the cognitive level of *application*. *Application* is the ability to use or apply information to real circumstances (Anderson & Krathwohl, 2001; Bloom et al., 1956).



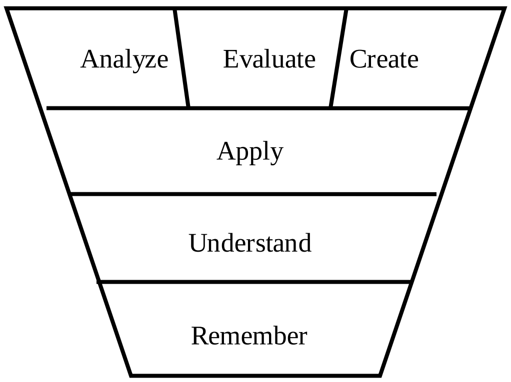
Note. Adapted from Bloom, B. S. & Krathwohl, D.R. (Eds.) (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook 1: Cognitive domain*. New York, Longmans.

Figure 2. Bloom's Taxonomy – Cognitive Domain

Great debate has occurred over the levels of the pyramid, specifically their order. The remaining three levels have been the primary focus of this concern. These levels are commonly considered the area of higher-order thinking: consisting of *analysis, synthesis,* and *evaluation*. Bloom and company's taxonomy suggests that *analysis*, or the interpretation of the whole by its structural elements, must be established prior to that of *synthesis*. *Synthesis*, or the creation or development of a unique or original product, must be established prior to the final step of *evaluation*, or the justification of value decisions and opinions (Bloom et al., 1956).

In 2001, Anderson and Krathwohl suggest that the last three sections are not in a fixed pyramid design, but rather at the same level of interacting utility (see Figure 3). At the heart of this new model, the cognitive development is the same. It is the interaction of the higher order thinking categories that have been established as being cyclic and interchanging as opposed to Bloom and company's previous linear model (Anderson &

Krathwohl, 2001). Again, both cognitive models share the same overall cognitive development and underlying characteristics differing only within the consistency of learning direction.



Note. Adapted from Anderson, L. W., & Krathwohl, D. R. (Eds.) (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Figure 3. Revised Taxonomy

Unlike the *cognitive* and *affective* domains, the *psychomotor* domain was not established by the original taxonomy committee. Instead, individual authors constructed their own interpretations regarding the physical category of educational objectives. The purpose of the psychomotor domain was to establish objectives that “emphasize some muscular or motor skill, some manipulation of material and objects, or some act which requires neuromuscular co-ordination” (Krathwohl et al., 1964, p. 7). In 1970, Dave produced the earliest form of the psychomotor taxonomy consisting of five distinct levels. By 1972, two other authors separately developed their own interpretation of the *psychomotor* taxonomy, Simpson and Harrow. Each is briefly outlined in Table 11.

Each description of the domain and its associated objectives is unique. The works of both Dave (1970) and Simpson (1972) appear to be constructed from a person's ability to perform designated tasks and/or skills. Dave's model commences from the point of *imitation* while Simpson's does not address the construct of *imitation* until the third level: *guided response*. Simpson's model begins with basic physical awareness, closer to that of Harrow's model. Harrow's explanation is more focused on the pure physical nature of the domain, seemingly ignoring concepts of skill and tasks and focusing directly on the pure actions of a person – not the product (refer to Table 11).

Still, the overall concept and direction of the learning expectations – as stated in the objectives – along this domain are equally shared. All of the *psychomotor* taxonomy models provide a hierarchical progression from which a person's physical abilities may be assessed, ranging from basic physical awareness to a much higher level skill combinations and modifications. It is vital to note that these taxonomies are simply a basis from which objectives are identified and assessments constructed. It is up to the individual user to decide which taxonomy is most appropriate for their particular situation.

The *affective* domain has been purposely left for last in this review of taxonomies. In reality the *affective* domain was actually the second taxonomy to be developed – circa 1964. The purpose of the *affective* domain was to establish objectives that "emphasize a feeling tone, an emotion, or a degree of acceptance or rejection" (Krathwohl et al., 1964, p. 7). This was not as simple a task to accomplish. The committee began by referencing educational definitions established through the works of Scheffler (1960). Terms that were discussed included “interest, attitude, values, etc” (Krathwohl et al., 1964, p. 27). It was quickly discovered that definitions were “difficult to devise, and their meanings tended to drift into the connotations and denotations which these terms encompassed in common parlance” (p. 27).

Instead, the committee reviewed the associated components of the defined affective characteristics and attempted to establish a theoretical order. To accomplish this task, the words originally identified for their affective foundations would be replaced as necessary with terms not directly associated with such a characteristic. This allowed for more freedom in the construction of an affective continuum and the associated educational objectives.

> “An examination of the category headings will show that we finally sought less commonly used terms, where, though we were still using noninventive stipulative definitions, the definitions given these terms and their descriptive definitions were more congruent.” (Krathwohl et al., 1964, p. 27, footnote)

A comparable theme was then chosen to aid in the construction of a continuum, *internalization*. After reviewing multiple learning theories, a previously established cognitive domain, and the determined affective components, *internalization* was the only applicable process that could establish a useful order. “It gave ordering to these components which appeared to be reasonably parallel to some of our theories about how learning takes place with affective objectives” (Krathwohl et al., p. 28).

Level	Level description
Dave, 1970	
Imitate/Imitation	The ability to observe a skill and/or pattern and attempt to repeat it Quality of performance is typically low
Manipulate/Manipulation	The ability to perform a function by following direction/instructions Practice is an expected attribute of this level
Precision	The ability to independently and accurately perform a task or skill with fewer errors, if any
Articulation	The ability to combine multiple skills into a consist and harmonic order
Naturalization	The ability to perform at a high level of skill with perceived ease, a natural and/or automatic action
Simpson, 1972	
Perception	The ability to use sensory cues to guide physical/motor activity
Set	The readiness to act, demonstration of awareness/knowledge of behaviors needed to carry out a skill
Guided response	The early stage of learning a complex skill: includes imitation, direction, and practice
Mechanism	The ability to perform a complex skill (at an intermediate level)
Complex overt response	The ability to perform a complete complex skill (at a proficient level)
Adaptation	The ability to modify learned skills to fit a new/special situation
Origination	The ability to develop an original skill or skill set for particular situation
Harrow, 1972	
Reflex movement	Reactions to situations that are not necessarily learned: segmental, intersegmental, and suprasegmental reflexes
Fundamental movements	Basic movements (i.e., walking, grasping, looking): locomotor, non-locomotor, and manipulative movements
Perception abilities	Response to stimuli: kinesthetic, visual, auditory, and tactile discrimination as well as coordinated abilities
Physical abilities	Stamina that is developed: endurance, strength, flexibility, and agility
Skilled movements	Advanced learned movement, possible combinations of physical actions: simple, compound, and complex adaptive skills
Non-discursive comm.	Effective body language: expressive and interpretive movement

Note. Adapted from Dave, R. (1970). Psychomotor levels. In R J Armstrong (Ed.). *Developing and writing behavioral objectives.* Tucson, AZ: Educational Innovators Press.
Note. Adapted from Simpson, E. J. (1972). *The classification of educational objectives in the psychomotor domain.* Washington, DC: Gryphon House.
Note. Adapted from Harrow, A. (1972). *A taxonomy of the psychomotor domain. A guide for developing behavioral objectives.* New York: McKay.

Table 11. Taxonomy of Educational Objectives – Psychomotor Domain

Krathwohl and company credit English and English's work defining psychological terminology as one of their inspirations regarding this choice. *Internalization* is defined as "incorporating something within the mind or body: adopting as one's own the ideas, practices, standards, or values of another person or of society" (English & English, 1958, p. 272; Krathwohl et al., 1964, p. 29).

Also noted is English and English's definition of *socialization* and its close relationship to *internalization*. This is primarily due to the reality that society, as well as, cultural circumstances aid in the development of an *affective* domain and must be considered as valuable factors when identifying objectives. Therefore, the committee had to design the taxonomy to "provide equally for the development of both conformity and nonconformity, as either role pervades individual behavior" (Krathwohl et al., 1964, p. 29). Additional interpretations of internalization as documented by Krathwohl and company were provided by Good (1959), Pitts (1961), and Kelman (1958). These interpretations reinforce the earlier variation provided by English and English.

The provided descriptions establish a developmental nature needed for the affective continuum, focusing specifically on the individual and their formation of attitude, values, and conduct at the highest level. They also align with concepts suggested by Freud regarding the development of an individual's superego through societal and family collectives (Krathwohl et al., 1964). Kelman (1958) identifies three processes regarding attitude change. These three processes – *compliance*, *identification*, and *internalization* – are all embodied within the affective continuum and its utilization of *internalization* (Kelman, 1958, p. 53; Krathwohl et al., 1964, p. 32). Kelman's attitudinal change process is described as:

> *Compliance* is suggested to occur when an individual adapts to another person's or group's authority in an attempt to gain some form or recognition and/or reward. Also, it is plausible that an individual experiencing this process may be conforming to an outside influence in order to avoid ridicule or punishment.
>
> *Identification* is suggested to occur when an individual adapts to another person's or group's authority because they have a strong desire or "want" to establish or maintain the collective and satisfying relationship. The individual demonstrates that they not only believe in the responses that they have adopted, but are happy to be recognized with such responses.
>
> *Internalization* is suggested to occur when an individual adopts an induced behavior (including associated ideas and actions) because it aligns with the person's existing value system. The individual is satisfied with the new behavior because it does not challenge the existing value system and integrates easily into the overall scheme (Kelman, 1958, p. 53; Krathwohl et al., 1964, p. 32)

Compliance is associated with the early phase of the *affective* taxonomy. The individual follows directions and carries out desired procedures. A person within this phase does not provide any indication of commitment toward a specific behavior without external motivation. *Identification* is associated with the central phase of the *affective* taxonomy. It is within this phase of development that an individual begins to "believe" in the introduced behavior. This level empowers a person to find satisfaction from actions associated with the behavior. The value system becomes formulated to the extent that external motivation is no longer a requirement. Beyond this point, the individual advances into the *internalization* phase. It is here that a person "has accepted certain values, attitudes, interests … into his [her] system and is guided by these regardless of surveillance or salience of an influencing agent" (Krathwohl et al., 1964, p. 32). At this phase, the individual is no longer adapting to the concerns or others, but rather reinforcing their own organized system. Kelman's variation of *internalization* is associated with the highest anticipated product of the *affective* taxonomy.

Kelman's processes are more specific than the broadly defined *internalization* model utilized by the taxonomy. Krathwohl and company within the documentation, itself, admit that there is some flexibility in the construction of the continuum due to the broad interpretations utilized.

> Since the boundaries of the categories are completely arbitrary and can be defended only on pragmatic grounds, it is possible that later work may suggest that other breaking points would be more satisfactory. The divisions between major categories have proved quite useful in the analysis of objectives. We feel more sure of the major divisions than of the subcategories, some of which appear to be easier to delineate than others. (Krathwohl et al., 1964, p. 33)

Table 12 displays the levels identified to represent the *affective* domain. Krathwohl and company have created five distinct levels of the *affective* domain: *receiving, responding, valuing, organization,* and *characterization by a value or value complex* (refer to Table 12). Each of these levels posses established subcategories. These varying subcategories are to aid a reviewer in delineating at which level an individual's affective development is.

The first level of the *affective* taxonomy is *receiving*. *Receiving* is comprised of three subcategories: *awareness, willingness to receive,* and *controlled or selected attention*. The overall focus of this level is an individual's willingness to accept or acknowledge the existence of an event, innovation, or object. Each subcategory attends to the varying degrees of this level. *Awareness* identifies that the individual is conscious of an innovation that has been implemented. *Willingness to receive* builds upon the simplistic nature of *awareness* demonstrated by the individual tolerating /enduring an innovation. At this subcategory a person is neither seeking nor are they actively evading the experience. The final subcategory is *controlled or selected attention*. The person experiencing this subcategory is actively seeking the favored aspects of the stimulus offered by the innovation. The pursuit for the enjoyable attributes of the object may cause an individual to ignore conflicting or distracting stimuli.

Responding is the second level of the *affective* taxonomy. This level is also comprised of three subcategories: *acquiescence in responding, willingness to respond,* and *satisfaction in response.* The overall focus of this level is demonstrated by an individual actively searching, attending, and/or signifying interest towards the stimuli. *Acquiescence in responding* is the preliminary subcategory for the *responding* level. An individual experiencing this subcategory will be content and yielding when prompted with specific direction regarding an innovation. The person would perform the required task as instructed with little and possibly shrinking resistance. The subsequent subcategory is *willingness to respond*. An individual representing this subcategory will voluntarily display the instructed behavior appropriate to the phenomenon. Little, if any, direction would be required as a person performs the duties; an obvious improvement from the preceding *acquiescence in responding*. The final subcategory, *satisfaction in response*, is comprised of an individual expressing an observable emotional response to the stimuli. The person is attaching emotional significance to the already voluntary actions – optimistically positive in nature.

The third level of the *affective* taxonomy is valuing. Valuing is comprised of three subcategories: *acceptance of a value*, *preference for a value*, and *commitment*. The overall focus of this level is to address the individual's reliability regarding their sense of worth – *value* – toward the phenomenon. *Acceptance of a value,* the first subcategory, is displayed through the succession of a person's emotional attribute relative to the innovation into an actual and identifiable value. It becomes something of worth beyond the object itself. *Preference for a value* builds upon the *acceptance of value* by allowing for the internalization of the created value. The innovation is now becoming associated with the person's identity. The final subcategory, *commitment*, is demonstrated by the individual's high level of doubtless devotion, a clear self-truth.

Organization is the fourth level of the *affective* taxonomy. It is comprised of only two subcategories: *conceptualization of a value* and *organization of a value system.* The focus of level is simply to integrate the created value(s) construct from the innovation into the individual's already existent scheme. *Conceptualization of a value* is the point when the created or new value is then compared to the already established values. Associations sought during this subcategory will be theoretical or conceptual and will not be composed in an apparent order.

Following *conceptualization of a value* is the subcategory *organization of value system*. In this subcategory, the person is actually constructing an ordered format that is in agreement and consistent with the preexisting value system. The person has now accepted the stimulus as a dominant value in relation to their existence.

Lastly, the fifth and final level of the *affective* domain is the *characterization by a value or value complex*. *Characterization by a value or value complex* is comprised of two subcategories: *generalized set* and *characterization*. The overall focus of this level is the complete internalization of the stimuli and the values created from its exposure. An individual's philosophical viewpoint is now defined by such internalization.

Level	Level subcategories
1.0 Receiving: The learner is willing to receive or to attend to the existence of certain phenomena.	1.1 Awareness: The learner is merely conscious of something – that he [she] takes into account a situation, phenomenon, object, or stage of affairs. 1.2 Willingness to receive: The learner is willing to tolerate a given stimulus, not actively seeking to avoid it. 1.3 Controlled or selected attention: The learner is controlling the attention so that the favored stimulus is selected and attended to despite competing and distracting stimuli.
2.0 Responding: The learner is actively attending and beginning to demonstrate interest.	2.1 Acquiescence in responding: The learner displays compliance when reacting to a suggestion with less resistance. 2.2 Willingness to respond: The learner is sufficiently committed to exhibiting the behavior voluntarily. 2.3 Satisfaction in response: The learner is experiencing/demonstrating a sense of satisfaction, or other positive emotional response following an innovation.
3.0 Valuing: The learner is displaying behaviors with a consistent sense of worth.	3.1 Acceptance of a value: The learner ascribes worth to a phenomenon, behavior, object, etc. 3.2 Preference for a value: The learner is internalizing the value beyond acceptance and identification while leading to commitment. 3.3 Commitment: The learner is personally holding the value with a high degree of certainty.
4.0 Organization: The learner is attempting to organize their values and determining the plausible interrelationships.	4.1 Conceptualization of a value: The learner is relating values to those previously held. Conceptualization of the value relationships will be abstract. 4.2 Organization of a value system: The learner is establishing an ordered relationship with the values that is harmonious and internally consistent.
5.0 Characterization by a value or value complex: The learner has consistently internalized the values to the point of personal description and philosophical association.	5.1 Generalized set: The learner has established a persistent and consistent response to a family of related situations or objects, an attitude cluster. 5.2 Characterization: The peak of internalization process, the learner's generalized sets involve greater inclusiveness and an emphasis on internal consistency … tending to characterize the individual almost completely.

Note. Adapted from Krathwohl, D.R., Bloom, B.S., & Masia, B.B. (1964). *Taxonomy of educational objectives: The classification of educational goals,* Handbook II. New York: McKay

Table 12. Taxonomy of Educational Objectives – Affective Domain

The *generalized set* is demonstrated by the individual's reliable responses to a collection of problems. In other words, issues that share certain characteristics will cause a person to respond in a similar fashion due to the "set" attitude. The subcategory *characterization* extends upon the *generalized set* by encompassing the individual almost completely, becoming a dominant attribute of the person's identity. *Characterization* is the highest level of the *internalization* process and therefore can dictate an individual's philosophy of life altogether.

The *affective* domain as established by Krathwohl and company is a broad and yet applicable interpretation of the subject. As defined in the writing, a more specific assembly of these characteristics would limit the use and flexibility of the objectives intended to be drawn from this taxonomy. It is for this reason that a combination of the *affective* taxonomy with another powerful instrument would be most beneficial. Therefore, the *Concerns-Based Adoption Model* (CBAM) and the *Taxonomy of Educational Objectives, Handbook II* (TEOII) will be utilized as the inspirational models to create measurable categories specific to student attitude and its implications toward STEM. Both foundational pieces address key attributes vital to the concerns of the researcher and the desired instrument, the elements of progressive change within an individual and the affective characteristics of such progressive change. Once specific categories are established, selected items will be formatted into the framework reflective of the instruments; however, with a different overall objective that does not allow the utilization of the original instruments' items without major reconfiguration.

Categories of Student Attitude

As presented earlier, the intended focus of the CBAM is the proposed evolution of an individual's feelings after having been exposed to and/or are presently experiencing a level of change. The professional development of educational staff and faculty was the original audience of this instrument but it has since grown to varying populations beyond education. The current CBAM addresses seven layers of concern related to the change experience, labeled as the Stages of Concern (SoC) (refer to Table 10).

The CBAM's SoC demonstrates a well defined measure for professional development, however, it does not clearly speak to the depth of student attitude toward STEM intended to be collected. CBAM documentation does define a concern as a "composite representation of the feelings, preoccupation, thought, and consideration given to a particular issue or task … depend[ent] on the person's past experiences and associations with the subject of the arousal" (Hall et al., 1987, p. 59). Interest has been defined as "a: a feeling that accompanies or causes special attention to an object or class of objects: CONCERN, b: something that arouses such attention" (Merriam-Webster, 2000, p. 238).

Both definitions identify with affective characteristics that are either developed or developing due to exposure based upon either experience or motivation. The similarities between these two terms, reinforced by their defined implications, serve well for the transitional development of a new instrument to measure student attitude toward STEM, especially when regarding student interest. However, interest does not completely cover the intended dimensions of student attitude toward STEM to be measured.

The *Affective Domain*, as supplied by the TEOII, covers the full range of "interests, attitudes, appreciations, values, and emotional sets or biases" required for an instrument of this magnitude (Krathwohl et al., 1964, p. 7). Unlike the CBAM, the TEOII does not establish a "concrete" hierarchy of progression through defined levels. Instead, each level is defined as a "range of levels" indicating the "extent to which the individual interacts with the phenomenon" (p. 26). Each level is presented in a decided order, but careful attention is given to the reality that subjects may wander between each of the developmental properties prior to reaching the highest indicated level – *characterization by a value or value complex*.

The TEOII also indicates that at any time a subject may revisit or re-align a previous established level. This flexibility of the system allows a measured attitude to be continuously revamped as the subject's experiences change. It is through the consideration of each of these instruments' attributes, as well as other available items, that an instrument to indicate student attitude toward STEM may be best constructed. The following categories of student attitude to be measured are preliminary designations derived from a review of the CBAM, TEOII, and a variety of psychological and educational vested materials. These categories may be revised during the review and testing process as needed.

Awareness

The first attitudinal category to be designated is *awareness*. *Awareness* is defined as a person "having or showing realization, perception, or knowledge" (Merriam-Webster, 2000, p. 80). This measure is a foundational piece of the instrument representing the most basic level of student perception, as demonstrated by both CBAM and TEOII documentations. *Awareness* indicates if the subject – i.e., student – can identify that they have been exposed to an innovation: i.e., any dimension of STEM.

It is important to clarify that the subject must be aware of the innovation in place – not just the school, the administration, or the researcher. If the subject is unaware of the innovation, then, further attitudinal development may be due to factors outside the implementation of the innovation: i.e., STEM programs. “The student brings to each situation a point of view or set which may facilitate or hinder his [/her] recognition of the phenomena” (Krathwohl, 1964, p. 176). This concern will require further testing beyond the current focus of this instrument.

This category also indicates if the subject is aware of their own initial interest toward an innovation. Items designated for *awareness* will demponstrate if the subject is “expressing a need to learn more of a general nature about the innovation…superficial overview… specific information” (Hall, 1974, p. 21). The subject is aware of the innovation, and is interested in seeking out more information regarding exactly what it is. However, it should be stated that the subject may not be capable of “discrimination or recognition of the objective characteristics of the [innovation], even though these characteristics must be deemed to have an effect” (Krathwohl, 1964, p. 177). This category of information being sought is simplistic in nature, limited to “general characteristics, effects, and requirements for use” (Hall & Hord, 1987, p. 60).

Ability

The designation of *ability* will comprise a second category of student attitude dealing specifically with the perception of a subject's capability regarding an innovation: i.e., STEM programs. Ability is defined as a "physical, mental, or legal power to perform … natural aptitude or acquired proficiency" (Merriam-Webster, 2000, p. 2). The SoC has two stages that lend to this category, *personal* and *management. Personal,* the third stage of the SoC, deals with the how the subject may identify with the innovation prior to a investment of self, "analysis of his/her role in relation to the reward structure … implications of the program for [the] self" (Hall & Hord, 1987, p. 60).

According to the SoC material, the subject is equipped with some preliminary knowledge regarding the innovation. Provided such information, the subject incorporates and possibly weighs the attributes of the innovation with pre-existing considerations: i.e., hobbies, prior training/education, level of commitment required. The personal stage may be carried throughout each of these four described categories; however, the focus here is the 'personal' attention to a subject's perceived ability. Such a factor may be a key determinant as to the subject's view of the innovation as an advantageous investment.

As described in the fourth stage of the SoC – *management* – deals with the "process and task of using the innovation and the best use of information and resources" (Hall & Hord, 1987, p. 60). The "process" and "tasks" are important aspects of an innovation when implementing a teaching technique or instructional tool; however, the instrument created here does not intend to measure the subjects' physical capabilities, but rather their perceived capabilities. An earlier form of the SoC (Hall, 1974) provides a more appropriate description of this stage (refer to Table 10). In the earlier version of SoC the fourth stage of concern is labeled as *early trial*. *Early trial* is described as being directed toward the subject's level of "confidence in his [her] ability to carry out his [her] role with the innovation" (Hall, 1974, p. 22). At this point in secondary education, it is assumed that the subject will have individual and/or collective experience with any one of the innovation components (science, technology, engineering, or mathematics). Such exposure may alter a subject's confidence due to the varied elements for each component.

The TEOII also lends itself well to the category of *ability*. The second level of the TEOII – *responding* – provides a great deal of attention to the subject "committing himself [herself] in some small measure to the phenomena involved" (Krathwohl, 1964, p. 178). Here it may be witnessed that the subject is not only aware of the innovation, but beginning to become comfortable with the concept, almost to the point of commitment. "[T]he learner is sufficiently committed … the element of resistance … is here replaced with consent … an emotional response, generally of pleasure, zest, or enjoyment" (Krathwohl, 1964, p. 179). Using this collection of interpretation, the category of *ability* intends to indicate to what extent the subject is confident and comfortable regarding the application and understanding of an innovation.

Value

The third category, *value*, intends to measure the importance of the innovation to the subject. *Value* is defined as "relative worth, utility, or importance" (Merriam-Webster, 2000, p. 1301). Elements of two SoCs – *personal* and *consequence* – may be witnessed as proponents to the development of this category. The *personal* level is an evident attribute, regarding the obviously ‘personal’ nature of a *value*. As previously mentioned in the category of *ability*, the “implications of the program for [the] self” (Hall & Hord, 1987, p. 60) may have a direct bearing on the overall attitude regarding an innovation. *Consequence* deals more with the external affect of an innovation and how it may impact others. This instrument is, at the moment, concerned only with the individual’s identification of personal value – external conditions will be addressed in later research.

The TEOII offers a more practical interpretation of *value* as defined in the third level by the same name. The importance of *value* is measured by the intensity in which the subject is “holding the belief” (Krathwohl, 1964, p. 181) of an innovation. Thereby, it may be assumed that the greater the intensity of a *value*, the greater the chance for the subject to develop a higher level of self identification and commitment toward an innovation. It is this intensity of *value* toward an innovation that the instrument is attempting to measure. A high degree of worth for an innovation may suggest that the subject is “sufficiently committed to the value to purse it, to seek it out, to want it” (p. 181). The relationships among values and the outlying factors that may influence a subject’s value system are not of concern at this point in the instrument development, but may later be implemented in future research.

Commitment

The fourth category, designated as *commitment*, exhibits the subjects’ desire to gain more from an innovation. *Commitment* indicates an acceptance of the innovation and its requirements beyond that of an initial exposure. It is defined as “an agreement or pledge to do something in the future; emotionally impelled" (Merriam-Webster, 2000, p. 231). Aspects of the higher SoC and TEOII levels are incorporated into the concept of this student attitude. Subjects experiencing high levels of *commitment* will indicate a "personal need to become more knowledgeable about the total operation within the program" as presented by *maximum benefit* used in the 1974 version of the SoC (Hall, p. 22). The subject will also begin to explore options to further reinforce the innovation for self and others – i.e., working groups, clubs, hobbies, and/or additional courses – beyond the course requirements, as identified within the SoC levels of *Collaboration* and *Refocusing* (Hall & Hord, 1987).

The intensity of student *commitment* may also indicate that the subject is interested in going beyond the limitations of the provided innovation, attempting to obtain a "more powerful alternative" (Hall & Hord, 1987, p.60). The "alternative," as it is suggested in the SoC of *refocusing*, could arrive in a multitude of forms and functions for a particular subject. Subjects arriving at this level may also share a strong "desire to incorporate new techniques" as well as a "desire for experiences that will broaden his [/her] outlook on his [/her] personal and professional life" (Hall, 1974, p. 23). This ideal is found not only in the SoC of *refocusing* but also the fifth level of the TEOII, specifically the subcategory *characterization* (5.2, refer to Table 12). "Persons at this level are pervasively controlled by an organized and integrated philosophy of life" (Krathwohl, 1964, p. 42). A full display of each of the attitudinal categories is presented in Table 13.

Category	Category description:	Inspired by:
Awareness:	- determines if the subject (i.e., student) can identify that they have been exposed to an innovation - measures if the subject is "expressing a need to learn more of a general nature about the innovation…superficial overview…specific information" (Hall, 1974, p. 21)	*SoC* - awareness (1987) - information *TEOII* - receiving
Perceived Ability:	- indicates to what extent the subject is confident and comfortable regarding their application and understanding of an innovation	*SoC* - early trial (1974) - personal (1987) - management *TEOII* - responding
Value:	- measures the importance of the innovation to the subject - indicates the intensity to which a subject is "holding the belief" (Krathwohl, 1964, p. 181)	*SoC* - personal (1987) - consequence *TEOII* - value
Commitment:	- indicates that the subject has a desire to gain more from an innovation. - identifies an interest that goes beyond the limitations of the provided innovation; attempting to obtain a "more powerful alternative" (Hall & Hord, 1987, p.60)	*SoC* - maximum benefit (1974) - collaboration (1987) - refocusing *TEOII* - characterization

Note. Adapted fom Hall, G. E. (1974). *The Concerns-Based Adoption Model: A developmental conceptualization of the adoption process within educational institutions*. Austin: Research and Development Center for Teacher Education, University of Texas, pp. 22-23, Appendix B.
Note. Adapted from Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process*. SUNY series in educational leadership. Albany, NY: State University of New York Press, p. 60.
Note. Adapted from Krathwohl, D.R., Bloom, B.S., & Masia, B.B. (1964). *Taxonomy of educational objectives: The classification of educational goals, Handbook II*. New York: McKay.

Table 13. Student Attitude Toward STEM – Preliminary Categories

It is not the purpose of this research to determine where the student is exactly intended upon finding such variations nor to what degree the "alternative" is related to the original innovation. Neither is the intent of this instrument to measure a subject's life philosophy. Rather simply, the instrument only intends to indicate that the subject is interested in options outside the initial model's limits and possibly beyond the realm of the attended high school. The multiple possible factors presented here will be investigated in later anticipated studies.

Variables to Be Tested

In an attempt to provide examples of construct validity for the student attitude toward STEM instrument, three independent variables were chosen and tested. The independent variables chosen were school, grade level, and gender. Each of these variables was considered to posses a measurable difference regarding STEM and STEM education. The differences between the levels of the independent variables should be demonstrated by the collected results of the student attitude toward STEM instrument. If the instrument does project measurable and significant differences between the identified levels of the independent variables, further evidence of construct validity would be provided for the student attitude toward STEM instrument.

School

The independent variable of school was selected for this study due to the strong implications and expectations of STEM programs and STEM education previously described. A self-proclaimed STEM-based high school program was utilized as one of the comparative examples for the school independent variable. This high school focused its education upon the principles of STEM while still providing its students with a state required college-preparatory education. A conventional, college-preparatory high school within the same metropolitan area was utilized as the other comparative school.

The specific STEM-based high school program is offered as an environment of alternative education for students within the metropolitan area. Students from any one of sixteen local high schools may apply to attend the STEM-based high school. According to the documentation provided by the STEM-based program, the attending students experience a personalized education when compared to traditional high school settings. Special attention is provided regarding the interaction and application for the subjects of mathematics, science, and technology.

After completing the required section of core subjects and passing the state's graduation examination, students are given the opportunity to actively participate as interns for local businesses and companies. This privilege is anticipated for eleventh and twelfth-grade students enrolled at the school. The positions available are reflective of the student's career and/or educational interests. Courses at local universities are also available for early college credit.

Within the documentation provided by the STEM-based high school is the school's intended focus upon student development regarding critical thinking and problem solving. This focus is part of the open-education format that was unique to the STEM-based high school, particularly for the students in the eleventh and twelfth-grade level. Additional intentions of the program are to develop social maturity and responsibility.

The college-preparatory high school offers a variety of program tracks for the attending students. Student abilities and interests lead them to tracks. A collection of mathematics and science courses is required for each student to complete. This is in addition to required courses in English, social studies, and foreign language. Depending on student progression through the required courses, elective courses are also available to complete a given semester schedule. The electives available depend upon student performance in other required courses. For instance, a student must perform well in mathematics and science courses to attend offered engineering courses.

The college-preparatory high school also offers students the opportunity to attend a career-technical education program. This program is focused upon students who intend upon entering the workforce immediately following the completion of high school. The students who select to attend this program may participate in all activities associated with the college-preparatory high school, including sports and clubs. No other specifications regarding educational outcomes or intern experiences were provided through review of the college-preparatory high school's public documentation.

Based upon these self-declared differences, as well as, the research implications previously discussed, the proposed unique educational environment employed by the STEM-based program should provide a different educational product when compared to a college-preparatory high school. This is not to suggest that elements of the STEM-based high school program cannot be identified within the college-preparatory high school or its students. Simply, the purposeful and intense focus provided by the STEM-based high school should provide a measurable difference in positive student attitude toward STEM when compared to the college-preparatory high school and its students. If this hypothesis were supported by analysis of the collected data, construct validity would be provided, specific to educational environments. For these reasons, the independent variable of school was selected for this study.

Grade Level

Elements of CBAM and TEOII previously detailed provide the foundation for the second independent variable to be tested, grade level. Both of these significant documents provide examples of progression specific to attitude development. As a student is exposed to an innovation over a period of time, feelings or thoughts towards that innovation develop – positively or negatively – into a more concrete structure. This process can extend to the degree that people identify themselves through aspects of the innovation. Of course, if the innovation is positively supported and reinforced throughout the time of exposure, it is only natural to assume that the end result of the innovation would be an increase in positive attitude toward the innovation.

Based upon this research, students exposed to elements of the content areas of STEM may construct attitudes that reflect their experiences. Student attitudes will develop as they explore varied aspects of the STEM content areas. However, it is assumed that each of the schools surveyed promotes positive attitude development toward the STEM content areas in addition to other educational subjects. This assumption is consistent for all schools utilized for this study and seemed to be a natural expectation of any educational environment.

Provided this reasoning, eleventh-grade students from the schools surveyed in this study should demonstrate more positive attitudes toward the content areas of STEM when compared to ninth-grade students from the same schools. If this hypothesis were supported by analysis of the collected data, construct validity would be provided, specific to progressive attitudinal development. For these reasons, the independent variable of grade level was selected for this study.

Gender

The third and final independent variable to be tested is that of gender. Gender differences regarding the content areas of STEM are well documented historically. Women have long since lagged behind men regarding career and professional involvement within STEM and STEM education. Though significant gains have been made in recent years to elevate these differences, a large gap still exists under specific fields of concern. According to statistics provided by the NSF, women have obtained more degrees in science and engineering than men between 1997 and 2006 (see Table 14). However, the degrees obtained by women have been heavily focused upon behavioral, social, and medical sciences. Men still exhibit a dominant position over the majority of engineering and experimental sciences.

Several studies have been conducted to address this concern of gender difference. A study conducted in 2007 concluded that women are less likely to obtain specific STEM degrees from higher education institutions (Tyson, Less, Borman, & Hanson, 2007). The researchers have based this conclusion on the history of science and mathematics courses taken by those selections of female and male students during their education experience from high school through college. This study demonstrated that the selection of female and male students took equivalent courses in science and mathematics from high school through entry collegiate courses. The difference was not discernable until review of higher level science and mathematics courses. Female students did not complete the higher level science and mathematics courses required to obtain certain STEM related degrees.

Field and sex	1997	1998	2000	2001	2002	2003	2004	2005	2006
TABLE C-1. Associate's degrees, by field and sex: 1997–2006									
Both sexes									
All fields	546,031	549,191	543,876	552,046	553,735	595,223	605,403	640,910	648,606
Female									
All fields	333,333	333,303	327,720	332,035	338,606	359,140	375,374	395,233	401,508
Male									
All fields	212,698	215,888	216,156	220,011	215,129	236,083	230,029	245,677	247,098
TABLE C-5. Bachelor's degrees, by field and sex: 1997–2006									
Both sexes									
All fields	1,186,589	1,199,579	1,253,121	1,257,648	1,305,730	1,359,843	1,407,009	1,437,200	1,473,735
Female									
All fields	661,307	673,865	716,963	721,625	751,773	783,866	810,817	828,938	851,824
Male									
All fields	525,282	525,714	536,158	536,023	553,957	575,977	596,192	608,262	621,911
TABLE E-1. Master's degrees, by field: 1997–2006									
Both sexes									
All fields	420,954	431,871	456,260	466,645	481,132	511,603	555,537	567,875	586,029
Female									
All fields	239,497	246,810	265,026	273,639	283,035	300,845	328,202	337,818	351,877
Male									
All fields	181,457	185,061	191,234	193,006	198,097	210,758	227,335	230,057	234,152

Note: Data not available for 1999.

Note: Adapted from the National Science Foundation, Division of Science Resources Statistics, special tabulations of U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 1997–2006.

Table 14. Science and Engineering Degrees Obtained Between 1997 and 2006

Another study conducted in 2008 suggested reasoning as to why this condition may have occurred. Issues concerning self-efficacy have been linked to the rate of women completing and conducting STEM and STEM education (Zeldin, Britner, & Pajares, 2008). The researchers interviewed collections of women and men regarding their capabilities toward science, technology, and mathematics. The persons interviewed were considered to be successful representatives of the three content areas. Both genders supplied shared factors that aided in reaching their level of achievement – family influence/history, peer support, and natural interest. These factors were very important and influential motivators for the female subjects interviewed during the study. The male subjects identified aspects of these factors, but they were secondary when compared to the strong indication of self-efficacy. The male subjects identified past successes as their primary motivator for progression within their fields.

Male subjects also found the accessibility of the three content areas to be a natural privilege and right. “They did not appear to question whether they would be able to create a life for themselves in science and mathematics related fields, but used their hardy self-perceptions to fine tune the many career alternatives they perceived to be available to them” (Zeldin et al., 2008, p. 1044). Female subjects, though now successful, commented on the difficulties they had to overcome regarding social expectations as well as identity challenges while obtaining positions in science, technology, and/or mathematics. Family support and reinforcement were regarded very highly by the women interviewed during the study.

The majority of research that has been conducted indicates the difference of ability and success between the two genders. Components that have been suggested throughout the review of these studies are the elements of motivation and support for women toward STEM and STEM education. DeWelde, Laursen, and Thiry (2007) and Seymour (2002) both indicate the female students begin to distance themselves from STEM content areas as early as middle school due to lack of supporting agencies. The previous review of the Zleldin and company’s research indicate how important supporting individuals or groups are to women success in STEM careers, as well as, their perceived efficacy regarding the content areas. Measurements of student attitude at this level could reveal early indications of this trend and thereby allow a STEM-based program to better address the condition.

Provided this reasoning, male students from the schools surveyed in this study should demonstrate more positive attitudes toward the content areas of STEM when compared to female students from the same schools. If this hypothesis were supported by analysis of the collected data, construct validity would be provided, specific to the current condition prevalent in secondary education environments. For these reasons, the independent variable of gender was selected for this study.

Summary of Variables to Be Tested

These three independent variables were chosen to represent varied groups that are anticipated to exhibit different levels of attitude toward STEM: school, grade level, and gender. These variables were chosen after extensive review of literature provided within the context of this chapter. The use of the three independent variables is only to provide examples of construct validity for the student attitude toward STEM instrument. Inferences to the samples and population based upon results obtained from the data analyses are not intended. Once the instrument has been developed and refined to the point of large scale application; inferences toward varied independent variables will be considered dependent upon obtained results and analyses.

Chapter 2 Summary

Chapter 2 provides an extensive review of the literature that was required to develop this study. The information presented included an overview of the development of STEM as it is currently defined. Also discussed was the continued and growing demand for STEM in the forms of programs, research, and the ever anticipated results. Following was an in-depth review of the concept of attitude in an effort to establish it as a basis for the instrument that is the focus of this study. Several existing studies and instruments were reviewed – focusing primarily upon the CBAM and the TEOII.

These valuable works will be the foundation for the attitudinal instrument to be implemented in this study. It is the anticipation and hope of this study that the resulting instrument will be a valuable tool from which STEM educational programs can improve upon and develop to better aid students in achieving STEM proficiency and literacy, also, that this instrument may better guide the funding and support of existing as well as future STEM-based programs. Chapter 3 will provide further description of the attitude instrument with clarification regarding item selection and development, subject involvement, data collection, and analysis.

CHAPTER 3: METHODOLOGY

Expansive amounts of money and time have been provided in the hopes that STEM-based programs will boost student interest and abilities related to STEM. Financiers include government and industrial organizations. However, these investments have yielded little results as demonstrated by the continued reports being constructed each year demanding greater STEM investment and results. The development of an instrument that can accurately measure student interest in STEM is crucial to STEM-based programs, their intended outcomes, the schools that implement them, and the companies that aid in their function as well as hope to reap from their products.

The intent of this study was to develop an instrument to measure students' attitudes toward STEM. Chapter 3 introduces the methodology utilized for the creation of such an instrument. A variation of the Concerns-Based Adoption Model's (CBAM) Stages of Concern (SoC); Taxonomy of Educational Objectives, Handbook II (TEOII); and varied attitudinal and STEM focused instruments were forms of inspiration to develop this new instrument. An item pool was created from an extensive review of existing instruments as well as other pertinent sources of information. The chosen items were submitted to a panel of experts representative of STEM and STEM education who aided in establishing content and face validity.

A selection of students from an available high school was surveyed to aid in refinement of the instrument prior to a larger-scale *known-group comparison* study. A focus group consisting of the high school students tested were interviewed following the completion of the instrument to establish item clarity. The *known-group comparison* involved two available high schools within the local metro area. Each high school represented a different interpretation of STEM and STEM education. The resulting data was used to establish instrument reliability and construct and content validity for the STEM attitude instrument.

Research Design

As indicated in chapter 1, the research question for this study is as follows:

1. Can a reliable and valid instrument be created to measure student attitude toward the four content areas of STEM?

To address this research question, objectives of the study were established. Each objective was addressed throughout the chapter of methodology in an attempt to guide the creation of a useful and applicable attitudinal instrument. The objectives of the study are listed and summarized in the following section.

Objectives of the Study

The principal objectives of this study were as follows:

1. Construct a new attitudinal instrument.

a. To create and identify categories specific to student attitude toward STEM based upon review of research and literature.

The categories were created by extensive review of the research and literature appropriate for the measurement of attitude and educational expectations. A panel of experts was utilized to review the categories and establish face and content validity.

b. To create and identify items specific to each of the established attitudinal categories intended to measure student attitude toward STEM.

Items were created specifically for each of categories. Existing instruments were reviewed, but only elements of the items found within the instruments were useable as forms of inspiration for the creation of new items. A list of items created for each of the attitudinal categories was review and approved by a panel of experts. Principal components analysis was applied to items to assure they were correctly assigned to each of the attitudinal categories.

c. To establish reliability and validity of the student attitude toward STEM instrument.

Reliability was established through the application of Cronbach's alpha procedure for each of the instruments, the categories, and the associated items. Validity was established through a collection of methods. Face and content validity was established by review of a panel of experts, related research, and a student focus group. Concurrent validity was established by application of a Pearson product moment correlation between the student attitude toward STEM instrument and the semantic differential attitudinal instrument.

2. To test the validity of the instrument between groups of anticipated difference, mean scores from a collection of independent variable groups were compared. The independent variable-based groups compared were school, grade level, and gender. These variables were chosen due to their anticipated differences regarding attitude toward STEM.

   a. To test mean scores between the STEM-based high school and college-preparatory high school students across all dependent variables and content areas.
   b. To test mean scores between the ninth-grade and eleventh-grade students across all dependent variables and content areas.
   c. To test mean scores between male and female students across all dependent variables and content areas.

Hypotheses

Based upon the objectives of the study, three hypotheses were created. Each hypothesis was created to act as a source of construct validity for the instrument if the null hypothesis is rejected. If the null hypothesis is accepted, validity is not necessarily violated. An acceptance of the null hypothesis may lead to future studies regarding the lack of differences between two groups of a given independent variable. The hypotheses are listed as follows:

H_1a: Students enrolled in a STEM-based college preparatory program will exhibit a more positive attitude toward STEM than students enrolled in a conventional college-preparatory program.

H_0a: Students enrolled in a STEM-based college preparatory program will not exhibit a more positive attitude toward STEM than students enrolled in a conventional college-preparatory program.

H_1b: Students exposed to STEM education for a longer period of time (i.e., higher grade level) will exhibit a more positive attitude toward STEM than students enrolled for a shorter duration (i.e., lower grade level).

H_0b: Students exposed to STEM education for a longer period of time (i.e., higher grade level) will not exhibit a more positive attitude toward STEM than students enrolled for a shorter duration (i.e., lower grade level).

H_1c: Male students will exhibit a more positive attitude toward STEM than female students.

H_0c: Male students will not exhibit a more positive attitude toward STEM than female students.

To accomplish the preceding objectives of the study and research hypotheses, the research study has been divided into three phases. Phase I consisted of the development of an instrument capable of measuring student attitude toward STEM (Objective #1a and #1b). A panel of experts was assembled and utilized for initial face validity as well as item development. Phase II verified the instrument through pilot testing and high school student focus group interviews (Objective #1). Results from the pilot test in addition to student responses were then used to revise the instrument before progressing into the final phase of the research study. Phase III completed the intended study by implementing the revised instrument at two high school settings; a conventional college-preparatory school and a STEM-based college preparatory school (Objectives #1 and #2, Hypotheses A through C).

Phase I: Instrument Development

As indicated in the review of literature (chapter 2), existing attitudinal devices were utilized as inspirational materials for the development of the instrument. The CBAM and TEOII were utilized as primary sources, while a semantic differential attitudinal instrument (SEMDIFF) was expected to be implemented solely as a comparative model. The combination of the CBAM and TEOII documentation allowed for the creation of four preliminary categories of student attitude toward STEM: awareness, ability, value, and commitment.

The four preliminary variables acted as categories for a framework to aid the researcher and the panel of experts in creating appropriate items for the intended instrument. A panel of experts in or related to the field of STEM and STEM education was assembled to review the items created for the instrument. This action was taken in an attempt to establish content validity (Gable & Wolf, 1993). Content validity is "the extent to which a certain set of items reflect a content domain" (DeVellis, 2003, p. 49).
The chosen experts were identified through their involvement and relationship with professional organizations associated with STEM and STEM education. The organizations that were utilized included NSF, ITEA, NCTM, Society of Manufacturing Engineers (SME), Ohio Manufacturing Association (OMA), Ohio STEM Learning Network (OSLN), Ohio Department of Education (ODE), and The Ohio State University (OSU).

Each professional was required to have at least 15 years of experience within one content area of STEM or STEM education and at least 5 years of experience within a secondary content area of STEM or STEM education. Each expert was contacted either via telephone or email by the researcher. In total, 15 professionals affiliated with the fields of STEM and STEM educations were contacted. Of the original 15, seven agreed to participate with the item development for this research study.

Panel of Experts: Demographics

- The panel of experts consisted of seven members – one female and six males.
- The years of experience in a single STEM content area ranged between 18 and 47; providing a mean of 30.6 years of experience.
    - Science related fields (n = 2)
    - Technology related fields (n = 1)
    - Engineering related fields (n = 3)
    - Mathematics related fields (n = 1)
- Each expert had at least 5 years experience in a second STEM content area as indicated by the expert.
    - Science related fields (n = 2)
    - Technology related fields (n = 1)
    - Engineering related fields (n = 2)
    - Mathematics related fields (n = 2)
- The experts' areas of professionalism included industry (n = 2), university (n = 2), secondary education (n = 2), and state organization/representation (n = 1).

The experts were unfortunately not available to meet as one complete group. The researcher met with experts as they became available during the instrument development process. Each expert was provided with the four preliminary categories created by the researcher. Additionally, a list of associated terms for each category was prepared using Microsoft Network (MSN) Encarta software. It is important to note that each list of terms was assembled not only from the category heading, but also the associated areas for which the category was intended to cover (refer to Table 13 in Chapter 2). The list provided to the experts is displayed in Table 15. The objective of the study was explained to each expert along with the reasoning for each category. The duration of the meetings varied between 20 and 60 minutes. Experts provided the researcher with items that they deemed necessary for an instrument focusing on student attitude toward STEM.

After meeting with each of the panel members, the researcher created a list of 50 initial instrument items. The preliminary list of items was then emailed to each panel expert. Revisions and corrections were offered from experts to be reviewed by the researcher. A final list of 34 initial items for each content area was assembled – 136 items total (see Table 16). These items were reviewed by an assembly of four undergraduate students. This informal review was performed purely for item clarity and face validity. It was assumed that the collection of undergraduate students would have closer ties to current high school students and therefore identify any obvious weaknesses in item wording and overall test construction.

The next process was to formulate each item into a scale that could measure across the four content areas of STEM. The reasoning for this was to avoid subjecting the high school students to the lengthy task of taking four different attitudinal tests. To accomplish this, a variation of a traditional Likert-scale was created and implemented. First, a four-level scale was chosen to span each of the STEM content areas.

Category	Associated Terms:
Awareness:	Interest, recognition, knowing, consciousness, attention, curiosity, concern
Perceived Ability:	Capability, skill, be able to, confidence, certainty, self-belief
Value:	Worth, significance, importance, usefulness, merit, regard
Commitment:	Pledge, dedication, devotion, potential, prospective, intention

Table 15. Student Attitude Toward STEM – Item Development

This was purposefully done in an attempt to avoid central tendency bias. The implementation of an even number of levels forces the subjected student to make a choice toward either the positive or negative side of the scale – depending upon the item.

Second, each level of the scale was arranged to represent all four content areas of STEM. This was accomplished by placing each scale in what is referred to as an "item block." Each block contains a single item as displayed in Figure 4. To the right of the item are four columns each containing the acronym of STEM listed vertically. Above the four columns is the assigned four-level Likert-scale categorically arranged from Most to Least. The directional value of the scale (see Figure 4) is dependent upon the item itself and is subject to change. For positively inflected items, the scale is Most (4) to Least (1). For negatively inflected items, the scale is Most (1) to Least (4). The design of this scale assigns a level of intensity to each of the columns provided. Students are instructed to mark only one box per content area across the block.

Instructions provided in the complete instrument (see Appendices B and D) indicate how selected students chose to respond to each of the four different content areas of STEM within an item block. The Likert-scale (most – least) allows students to select a level of intensity for each content area in relation to the item presented. It is vital that students look upon each content area independently in regard to the provided item – e.g., I like science – and not at the collection of content areas – e.g., I like science, technology, engineering, and mathematics.

Question A	Most ------------- More ------------- Less ------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Figure 4. Student Attitude Toward STEM – Item Block

Semantic Differential

The creation of the *Semantic Differential* (SEMDIFF) scale is associated with the works of Osgood, Suci, and Tannenbaum in 1957. Their published work, *The Measurement of Meaning*, was the first document to address SEMDIFF. However, as stated within the text itself, it would be the collective works of previous scholars that would allow these researchers to create such a universal affective scale. “The notion of using polar adjectives to define the termini of semantic dimensions grew out of research on sysnesthesia with Theodore Karwoski and Henry Odbert at Dartmouth College" (Osgood, Suci, & Tannenbaum, 1957, p. 20).

Category	Associated Items:
Awareness:	1. I like to read about:
	2. My school offers courses in:
	3. My school does not offer after school programs in:
	4. I enjoy watching TV shows involving:
	5. I do not want to learn more about:
	6. I do not enjoy taking courses in:
	7. Courses in [subject] are available to me
	8. I dislike the challenge of:
	34. I like:
Perceived Ability:	9. I am good at projects involving:
	10. [subject] is difficult for me:
	11. I perform well in [subject] courses:
	12. I can not handle advanced courses in:
	13. [subject] is simple:
	14. I do not worry about taking tests in:
	15. I struggle in [subject] courses:
	16. I do not understand:
	17. Homework in [subject] is easy:
Value:	18. [subject] is important
	19. What I learn in [subject] has no value to me:
	20. I believe there is a need for:
	21. I need:
	22. Learning [subject] will not help me:
	23. [subject] is good:
	24. I care about developments in:
	25. [subject] is not worth my time to understand:
Commitment:	26. I would dislike more/advanced courses in:
	27. I would like to participate in more after-school programs in:
	28. I am curious about a career involving:
	29. I am interested in advanced programs involving:
	30. I have no interest in discovering new ways to apply:
	31. [subject] is not a vital part of my perceived future:
	32. I intend to further develop my abilities in:
	33. I will continue to enjoy the challenge of:

Table 16. Student Attitude Toward STEM – Pilot Study Items

Sysnesthesia is defined as “a phenomenon characterizing the experiences of certain individuals, in which certain sensations belonging to one sense or mode attach to certain sensations of another group and appear regularly whenever a stimulus of the latter type occurs” (Osgood et al., 1957, p. 20). This type of possible “neural cross-circuiting” led to a variety of research studies attempting to establish a link between human senses, thinking, and emotions. Karwoski and Odbert began by establishing an experience-based connection between music and color in 1938. This connection was found to occur frequently in approximately 13% of the sample; however a larger number reported that they experienced this connected occasionally (Osgood et al., 1957). Karwoski, Odbert, and Eckerson continued this research and established a plausible connection between mood, color, and music by 1942. Subjects were exposed to a series of short musical excerpts from a determined collection. The subjects were instructed to select a mood that best fit the music excerpt they had just heard. The music was played for the subjects a second time when then they were asked to select only a color that was appropriate for the musical selection.

A second sample of subjects was also chosen for this research. This group was only provided the list of mood adjectives; no auditory stimulus was provided. They were instructed to select the most appropriate color for the moods supplied. Both groups shared a strong correlation between moods and colors (Osgood et al., 1957). One example of the association that the subjects’ agreed upon was the “fast, exciting” music and the verbal expression of “red” or “hot” as the representative imagery. In complete opposition to this example, the subjects also agreed that “slow, melancholic” music is associated with terms like “blue,” “cold,” or “heavy.”

Osgood joined Karwoski and Odbert in 1942 helping to reinforce the visual connection to the already associated auditory, verbal, and emotional modalities. For this research, the subjects were asked to draw pictures that depicted the music that they heard. The selection transitioned from a louder tone to a softer tone. The results were a variety of drawings that were “functionally or meaningfully equivalent responses to the same auditory stimulus, and they display continuous translation between modalities” (Osgood et al., 1957, p. 22).

Osgood and company also conducted an experiment which would be the first to resemble the later SEMDIFF scale. Approximately 100 sophomores were provided with a verbal metaphor test at Dartmouth College (Osgood et al., 1957). The previous research studies had supplied both auditory – mood and visual – spatial characteristics that could be constructed into divergent pairs (i.e., loud – soft; small – large). For example, for each set of auditory – mood pairs, one word was capitalized (i.e., LOUD – soft). When subjects were presented with this pair, they had to pick from the visual - spatial pair which term best associated with the capitalized word (i.e., LOUD – soft; SMALL – LARGE)(Osgood et al., 1957). Several combinations of pairs were displayed within the test in addition to the provided example. Again, a strong concurrence was found between the adjectively identified modalities.

Osgood’s undergraduate thesis embellished upon this line of reasoning. He studied field reports from anthropological studies from five primitive cultures.

Each of these cultures came from geographically independent regions. Osgood was attempting to see if the predominate culture was responsible for the relationships between the observed modalities or if such consistency exists among the human race (Osgood et al., 1957). After reviewing each of the anthropological reports "essentially the same types of translations [regarding observed modalities] again appeared" (Osgood et al., 1957). Examples included relating the concept of *good* to terms like *God, light, up, warm,* and *happy*. In complete agreed upon opposition, the concept of *bad* related to terms such as *dark*, *cold*, *wet, sad, down,* and *deep* (Osgood et al., 1957). Karwoski, Odbert, and Osgood established a summary of this complete field of work by stating:

> [T]he process of metaphor in language as well as in color-music synesthesia can be described as the parallel alignment of two or more dimensions of experience, definable verbally by pairs of polar adjectives, with translations occurring between equivalent portions of the continua.
> (Osgood et al., 1957, p. 23)

In 1946, Osgood and Stagner began to apply a set of scales in an attempt to profile social stereotypes. The scales were constructed from the polar word pairs created from the previous research. They developed a continuum between the polar terms that consisted of a seven-step scale, a semantic scale. This new measurement device was administered to subjects throughout the period of World War II in the United States. The research demonstrated that social stereotypes could be profiled by the semantic scales and that these scales fell into identifiable and inter-correlated clusters (Osgood et al., 1957).

The results of this early collection of conceptual research would allow the researchers to postulate a more definite semantic space, "a region of some unknown dimensionality and Euclidian in character" (Osgood et al., 1957, p. 25). To accomplish such with "maximum efficiency," the researchers attempted to identify the available dimensions through factor analysis. At least three different factor analyses were conducted to accomplish this. The first analysis – a centroid factorization, graphic method – was conducted with a sample of 100 students enrolled in an introductory psychology course. These students were paid for their participation.

Analysis I – SEMDIFF. While constructing the first semantic instrument, the researchers created approximately 1,000 test items to be reviewed. Instead of requesting every student to respond to a 1,000-item test, only 40 items, randomly chosen, were provided in each student instrument. Each item was carefully paired with only one of the 20 researcher-chosen concepts. They included *lady, boulder, sin, father, lake, symphony, Russian, feather, me, fire, baby, fraud, God, patriot, tornado, sword, mother, statue, cop*, and *America* (Osgood et al., 1957). The concepts were purposefully rotated as the instruments were created in order to prevent multiple concepts on a single test. The final student instrument could comprise any order of the 50 chosen polar/semantic scales. These scales were derived from the *Kent-Rosanoff* list of stimulus words as well as the researchers own input. The student had to pick a point along the semantic space between the two displayed divergent terms that best represented the depicted concept.

The results from the student instruments were generated into a matrix of intercorrelations – 50 scales x 20 concepts x 100 subjects. This scale was then broken down into a single intercorrelation – 50 scales x 50 (subjects/concepts). Subjects and concepts values were summed over to "avoid spuriously low correlations resulting from low variability of judgments on a single scale" as well as "to set up a semantic measuring instrument which would be applicable to [both] people and concepts in general" (Osgood et al., 1957, p. 35). After applying the data to *Thurstone's Centriod Factor Method* four factors were extracted. These factors were then orthogonally rotated into a simple structure.

Factor I accounted for the majority of total variance from the data – approximately 34%. Factor I was identified as *evaluative* because of the high loading semantic scales (polar sets) identified with the factor. Some examples of these scales included *good-bad, happy-sad, clean-dirty,* and *fair-unfair*. Each associated scale demonstrated a loading of .75 or better and were primarily loaded only on factor I. Factor II, *potency*, accounted for almost 8% of the total variance. While some of the scale loadings were very high on factor II (large-small, strong-weak, heavy-light, all with a loading of .62), some scale loadings were contaminated by having equally high loadings on other factors, specifically the *evaluative*. Examples include *hard-soft* (factor I = -.48, factor II = .55), *loud- soft* (factor I = -.39, factor II = .44), and *rough-smooth* (factor I = -.46, factor II = .36).

Factor III decidedly comprised the *activity* factor based upon the physical nature of the high scale loadings identified. The *activity* factor accounted for only 6% of the total variance. Scales (polar sets) identified for this factor included "*fast-slow* (.70), *active-passive* (.59), and *hot-cold* (.46)" (Osgood et al., 1957, p. 38). Like the previous *potency* factor, the *activity* factor shared some considerable scale loadings with the *evaluative* factors – namely *red-green* (factor I = -.33; factor III = .35), *young-old* (factor I = .31; factor III = .32), and *ferocious-peaceful* (factor I = -.69; factor III = .41). The fourth factor was not considered as a valuable attribute for the research due to its overall low scale loadings and small percentage of total variance (~2%).

These three identified factors accounted for almost 50% of the total variance and almost 70% of common – extracted) variance. These percentages negated both measurement error and the remaining 50% of total variance yet to be explained. The researchers discovered after reviewing the original analysis, that some bias may be present. In fact, after a quick small scale analysis it was found that the 20 concepts chosen by the researchers for the study may be non-representative of the scales. It was also proposed that the factors themselves may not exist if the scales were to be implemented in another technique or study. Therefore, a second analysis was conducted.

Analysis II – SEMDIFF. The second analysis only included 40 students. The students were noted as being chosen from the same pool of undergraduate students as the previous exercise – assumed to be from Dartmouth. The same 50 scales were implemented in this analysis. In a stark contrast from the previous analysis, no concepts were utilized in this research, thereby removing the attribute as a contaminating variable. Instead, the students were provided with instruments comprised of “force choice” items. A similar approach was used in the earlier study conducted by Karwoski, Odbert, and Osgood (1942).

The forced choice method is utilized to see if two sets of polar terms have an identifiable relationship. The first polar term set would have one word completely capitalized while the opposing word is in all lowercase text – e.g., FRESH-stale.

The second pair – directly adjacent to the first polar set separated by a semi-colon – would have both words in lowercase text – e.g., FRESH-stale; long-short. In this example, a student would have to choose one of the words from the second polar set that best fit the capitalized word from the first set. Again, this is done without a prevailing concept.

A total of 1,225 items were created by pairing the original 50 polar term sets with each other. Like the first analysis, a rotational item selection method was utilized for the 40 student instruments created. Another 50 x 50 matrix was created from the subjects' responses. The factoring applied in this analysis differed from the earlier example. The utilized technique was considered to be equal to Thurstone's diagonal method. Unlike Thurstone's method, this "D-method" of factoring processed raw scores collected from the instruments instead of correlation coefficients. This application assisted the researchers by yielding results that are "highly similar to the factors given by more conventional methods, e.g., the centroid method" (Osgood et al., 1957, p. 332).

> The method results in a matrix of coordinates (loadings) for each variable on a set of dimensions (factors) which are orthogonal to each other. Each dimension coincides with a variable chosen as a pivot. The higher the coordinate of a variable on a dimension, the more closely related is that variable with the dimension. (Osgood et al., p. 42)

The dimensions that were identified as pivotal in this study were (I) good-bad, (II) rugged-delicate, (III) sharp-dull, (IV) heavy-light, and (V) empty-full. Once identified, the first and second analyses were compared both qualitatively and quantitatively.

Results from the two analyses comparison provided further reinforcement for the *evaluative* factor. Both factor I and dimension I indicated high agreement quantitatively (*e* = .97, *r* = .97). Qualitatively, this was also consistent. Similar scales depicted equally high loadings on both analyses; *good-bad, nice-awful,* and *beautiful-ugly* are some examples. *Potency*, however, displays what was considered "the poorest correspondence between factor and dimension" (Osgood et al., 1957, p. 44). The correlation of variables (*r*) was only .45 and .63 for the factorial similarity (*e*). The highest loading items between both factor and dimension measures were *strong-weak, large-small,* and *heavy-light.* Dimension III and factor III comprise the *activity* factor. These analyses measures proved to be quantitatively stronger than the *potency* factor (*e* = .74, *r* = .68). Qualitatively, the polar sets identified fit the anticipated factor well; exemplified by the sets *sharp-dull, active-passive,* and *fast-slow* which scored the highest loadings on both measures.

Even though the three factors, *evaluative, potency,* and *activity,* were identified by both analyses and correlated through their collective data, questions still persisted as to the remaining variables. These variables were the polar terms that did not load upon any of the three dominate factors. The issue was traced back to the original creation of the polar terms. It was proposed that too much emphasis was placed on evaluative terms. Though this may be a completely human factor, a purposeful attempt to curb this issue by embarking on a larger, more extensive sampling procedure was undertaken. The anticipated result would be a list of terms representative of all possible factors and independent of research biases.

Analysis III – SEMDIFF. Roget Thesaurus (1941 edition) was used as the word bank for this analysis. It was chosen because it provided both a large collection of plausible terms and lists of terms already arranged in polar sets. The senior researcher (Osgood et al., 1957) chose the list of terms to be used. A panel of judges then reviewed the list, selecting the most probable polar sets. A problem would arise when the polar sets chosen were too many for the computer at the time to compute. The 289 polar sets would have to be cut down to 76 for the computer to handle the process.

To address this, the research team involved students enrolled in advanced advertising courses. These students were thought to posses certain sensitivity toward the "subtleties in word meanings" (Osgood et al., 1957, p. 48). The students were given the word pairs on a series of cards. They were asked to divide the cards into 17 categorized piles of shared meaning. The piles could be defined as the students saw fit and were not required to posses a specific number of cards. After the students finished their review of the polar terms, the researchers mirrored the same process. Their combined efforts trimmed the 289 polar sets to the acceptable 76 polar sets.

The researchers then selected 100 undergraduate students to participate in the third analysis. Like the first analysis, 20 concepts were chosen. These concepts were selected to represent a wide variety of influence, of which only five concepts from the original analysis were utilized. Instead of rotating the concepts – as done in analysis I, the concepts were divided into 20 separate booklets. Each booklet contained four pages of the 76 polar sets. Each page had the concept clearly printed on top of the page.

The students were asked to complete all 20 booklets as part of their participation in the research study. The researchers instructed the students to complete one page at a time in the booklet. In other words, the students were directed to complete only the first page in each of the booklets. Once completed, they were then instructed to move on to the second page. This was done purposely to avoid boredom addressing one single concept for an extended period of time. The students were also allowed to take several breaks during the data collection process as they saw fit.

The *centroid factor analysis* was again used to process the data. Eight factors were identified with the first three accounting for most of the variance. The first three identified factors were again *evaluation*, *potency,* and *activity*. To provide greater clarity in the analysis, a *quartimax rotation of the centriod* was implemented. This procedure implements a fourth power criterion as opposed to the least squares criterion utilized in the *centriod factor analysis* (Osgood et al., 1957). Even after rotation, the same three factors still were clearly identified.

It is these three factors that serve as the basis for the semantic differential instrument as it exists today. The *evaluative*, *potency,* and *activity* factors (*EPA*) along with their associated polar sets can be constructed into a variety of formats dependent upon the researcher's intent. However, the researchers that aided in establishing this simple to use and easily implemented instrument have suggested a certain number of criteria to follow when creating a tailored instrument (Al-Hindawe, 1996).

The first criterion recommended is that of an EPA factorial composition. The researchers recommend that all uses of the SEMDIFF employ polar sets representative of all three associated factors, evenly. Immediately this raises some very important questions – why should all factors be equally represented if they are not producing equal loadings in response? The review of the work of Osgood and his associates provided evidence that the *evaluative* factor is the most powerful of the three factors. The reason why the evaluative factor is the most powerful factor may actually be provided by other researchers' examinations of the SEMDIFF and its components.

One such concern with the SEMDIFF is the concept of *bipolarity*. *Bipolarity* is the assumption "that two contrasting adjectives plotted in the semantic differential space would be about equidistant from the neutral center point, and they also would be opposite one another so that a line passing between them would also pass through the center" (Heise, 1969, p. 407). *Bipolarity* was found primarily with the *evaluative* polar sets, but it was not a frequent occurrence with either *potency* or *activity*. *Potency* and *activity* were found to predominately *unipolar*, however, still retaining a larger amount of variance. Such a reality suggests that the two terms may not be equally balanced over the semantic space as is typically assumed. This condition may be countered by averaging the *unipolar* scores (Heise, 1969). Once the scores are averaged, the *unipolar* data can better correspond to the *evaluative* bipolar data. Therefore, a careful review of the data is required to avoid the *unipolar* concern from becoming a reality and possibly altering the collected data.

The treatment of the data in this fashion also provides greater strength to the overall EPA factors. This greater strength reinforces the recommendation provided by Osgood and his associates when developing a new variation of a SEMDIFF. However, such data modifications may not be required nor may they be possible in all situations. Some of the issues regarding SEMDIFF and its items may have less to do with their factorial identification and more to do with the polar terms themselves.

A second criterion as indicated by Osgood and his associates was that of relevant polar sets (Osgood et al., 1957). It is up to the discretion of the perspective researcher to select polar sets that fit the intended research. Careful attention is recommended; picking irrelevant polar sets may produce neutral results or limited variances among the subjects' responses. Bias is an area of significant concern when selecting polar sets. As mentioned previously, it is one of the areas that researchers may find problematic.

Several instances of bias can be found within seemingly plausible polar sets and contexts. One example of this particular concern is regarding cultural or societal bias. This sort of bias can occur nationally as well as internationally. For example, words like *ambition* and *self-confidence* are viewed as positive and worthy traits by American standards, but to the Japanese, these two words have negative and egocentric connotations (Al-Hindawe, 1996; Furuya-Nakajima & Vogt, 1990; Gaies & Beebe, 1991). Even on a national scale, the word *career oriented* as found in Australian culture has been observed to represent both positive and negative traits (Al-Hindawe).

Bias can also be gender sensitive. Men and women may respond to certain SEMDIFF items with different interpretations of polar sets. Polar sets like *tough-weak*, *hard-soft*, and *masculine-feminine* are commonly associated with this concern (Al-Hindawe, 1996). Social desirability and expectations may weigh in as contributing factors in regard to this bias. Nickols and Shaw (1964) noted that social desirability affected SEMDIFF instrumentation only when the concept items were “salient” or overtly significant to the individual. Special note must be taken into account regarding this overall bias. “The researcher has no objective way of knowing whether the attitude of the judge is positive or negative for such adjectives without some empirical knowledge of the social values of the group under investigation” (Al-Hindawe, p. 6).

The third criterion suggested is an extension of the second; semantic stability in regard to the concepts and the subjects (Osgood et al., 1957). This refers directly to the relationship between the concept and the subjects’ interpretation of the provided polar sets. The researcher may address this buy taking time to assign appropriate polar sets to the desired concepts. Examples include using the polar set of *large-small* for concepts like *mountain* and *nail* and not concepts like *heaven* and *fear*.

Lastly, the fourth and final complete criterion is that of dealing with nonlinearity. This concern has been implied as a possible complication previously in regard to gender bias and social desirability. The two polar terms that comprise a set must be opposites, representing a “line” that accounts for the semantic space – hence linearity. However, if both words can be interpreted as either positive or negative – regardless of the provided concept – the linearity is not maintained. Again, this criterion is similar to the second suggested criterion recommended for researchers; careful attention and selection regarding the intended concepts, subjects, and polar sets is critical for a successful SEMDIFF.

Each of these suggestions was taken into consideration when creating the SEMDIFF to be implemented in this study. The main function of the SEMDIFF is to be a comparison instrument for the student attitude toward STEM instrument. It is anticipated that the polar sets selected for the SEMDIFF will be equitable to the categories designated for the student attitude toward STEM instrument. Therefore, the student scores on these particular polar sets should correlate with the students' responses on the associated category items.

The SEMDIFF utilized in this study was comprised of bi-polar pairs that were purposefully selected to best address varying interpretations of the STEM content areas. Special attention was given to attitudinal attributes such as interest, value, and perceived ability. After reviewing the documentation regarding the creation and implementation of a SEMDIFF, certain bi-polar pairs were selected. Some of the bi-polar pairs utilized were the highest loading of each of the primary SEMDIFF principal components (*EPA*) as identified by Osgood and his associates. This was purposefully done as it was recommended by Osgood and his associates that the *EPA* relationship be maintained in the development of a SEMDIFF. However, in several other reports, this criterion was not clearly upheld. In fact, most research documentation merely refers to the second criterion when constructing a SEMDIFF; that is to select bi-polar pairs that best reflect the research intended (Ary et al., 2006; DeVellis, 2003; Gay et al., 2006; Osgood et al., 1957).

The first six bi-polar pairs – *good-bad, like-hate, welcome-loath, interesting-dull, pleasant-foul,* and *optimistic-pessimistic* – were selected to represent the *evaluative* principal component from the Osgood and company research. Of these sets, *good-bad* and *optimistic-pessimistic* were two of the highest loading sets selected from SEMDIFF research from the *evaluative* principal component (Osgood et al., 1957). Both of these bi-polar pairs were selected to align with the proposed *value* category. *Interesting-dull* and *pleasant-foul* were modifications of high loading sets in order to associate them with the created interest categories (*awareness* and *commitment*) created for the attitude instrument. *Pleasant-foul* is a modification of *fragrant-foul*. *Pleasant* was substituted in place of *fragrant* so that the students would focus less upon a sense of smell and more on a feeling.

The bi-polar pair *interesting-dull* is actually taken from a high loading *activity* bi-polar pair – *interesting-boring*. This modification was made due to the equally high loading of *interesting-boring* on the *evaluative* principal component. *Dull* was used in place of boring to better associate the bi-polar pair with a feeling as opposed to a physical attribute. *Like-hate* and *welcome-loath* were both created specifically for this SEMDIFF based upon a review of the categories and expected responses. No direct relationship with previous SEMDIFF models was found in the research. Again, these bi-polar pairs were created to reflect not only the evaluative construct of the SEMDIFF research, but also the interest categories (*awareness* and *commitment*) and value category (*value*) of the student attitude toward STEM instrument.

The *potency* principal component did not directly correspond with the established categories for the attitude instrument. *Potency* was described as defining the "general nature" of a concept (Osgood et al., 1957). After reviewing the bi-polar pairs recommended by Osgood and his associates, a possible correlation to both the *value* category as well as the overall construct of *attitude* was arrived upon. The bi-polar pairs selected were *hard-soft, light-heavy, feminine-masculine, severe-lenient, weak-strong,* and *tenacious-yielding* (Osgood et al., 1957). It was therefore deemed that these sets, though indicating no clear connection to the instrument's created attitudinal categories, were necessary for the overall attitude construct as well as to maintain the full power of the SEMDIFF instrument. These six particular bi-polar pairs used were pulled directly from the text due to their high loadings associated with the SEMDIFF and the *potency* principal component.

The *activity* principal component also consisted of six bi-polar pairs: *active-passive, excitable-calm, cold-hot, simple-complex, easy-hard,* and *fast-slow.* These six bi-polar pairs are considered to associate with the ability – perceived ability) category in the student attitude toward STEM instrument. *Active-passive, excitable-calm,* and *hot-cold* are the purest loading items regarding the activity principal component as determined by Osgood and his associates. *Simple-complex* had high loadings on the *activity* principal component but also contained a fair amount of loading on the *evaluative* principal component. *Fast-slow* also had a high loading on the *activity* principal component, but shared similar loadings on the *potency* principal component. *Easy-hard* was developed purposefully for the *activity* principal component based upon the *ability* category from the attitude instrument.

Four SEMDIFF instruments were provided in the initial instrument. Each represented a different content area of STEM. Instructions and examples were provided in addition to an explanation of the short time and quick response required for an SEMDIFF instrument. It was anticipated that the created SEMDIFF instrument (displayed in Figure 5) would offer the research study a fair and concise comparison instrument to add to the construct validation of the attitudinal instrument. Students' overall attitude scores on the SEMDIFF instrument per each content area should be statistically significant with the overall attitude scores on the attitude instrument per each content area. The SEMDIFF instrument was only implemented in the preliminary pilot study. After all the data were compiled from the pilot study, students exposed to the instrument were interviewed regarding their experience with the SEMDIFF as well as the attitude instrument.

Phase II: Pilot Study

Once the complete instrument was assembled, a high school within the local, metropolitan school district was contacted and utilized to participate in an initial review of the instrument. The selected high school was picked from a list of schools participating in a STEM education project. It was also selected for its close proximity to the university and small student population.

Population

This suburban high school had a grade level population distribution almost equivalent to that of the STEM-based program utilized in the *known-group comparison* in phase III. Statistics provided by the high school indicated that there were 415 students enrolled in all four grades (grades 9-12) as of January, 2009. The high school curriculum was predominately college-preparatory, but offered both work program and career and technical education as optional fields of study for the students.

The career and technical education program was offered as a supplemental curriculum; therefore, the interested students were transported to another local district school that offered the desired program. The work program was only offered to eleventh and twelfth-graders who were over the age of 16 years. Industrial technology was offered as an elective course. The courses were heavily traditional: consisting of metals, woods, mechanical drawing, and technology. The high school met state performance requirements for college-preparatory academics, but their technology program resembled an industrial arts format which has long since been renovated.

Pilot Sample

Seventy-four high school students were conveniently sampled to participate in the pilot study. The student sample was drawn from an accessible school population that was randomly selected from pre-existing homerooms established by the high school administration. Though small, this sample size was deemed adequate for this particular phase of the research study. “There are no hard and fast rules for determining the “correct” number of participants” (Gay et al., 2006, p. 114). However, there are many suggestions regarding adequate sample size specifically to aid in greater population generalizability. In DeVellis's *Scale Development, Theory and Application* Tinsley and Tinsley are noted as suggesting a ratio of 5 to 10 subjects per instrument item with a ceiling of 300 participants (DeVellis, 2003). Also mentioned is Comrey's suggestion of 200 research participants for instruments with less than 40 items (DeVellis, 2003).

				CONTENT AREA			
EVALUATIVE	bad						good
	like						hate
	loathe						welcome
	interesting						dull
	pleasant						foul
	optimistic						pessimistic
POTENCY	hard						soft
	light						heavy
	feminine						masculine
	severe						lenient
	weak						strong
	tenacious						yielding
ACTIVITY	active						passive
	excitable						calm
	cold						hot
	complex						simple
	easy						hard
	slow						fast

Figure 5. Student Attitude Toward STEM – Semantic Differential

It was understood by the researcher that such a small sample may provide sensitive results from the data analysis as well as limited population generalizability. However, the primary purpose of the pilot study was to refine the instrument by establishing item reliability and validity prior to the study on a larger scale and sample size. Also, collected demographic information aided in addressing this concern as well. The third phase of this research study directly addressed the sample size proportion as suggested by other researchers.

Research Materials

Every student available to participate in the research study was provided a research packet. Each packet contained the following items:

- white envelope
- clear plastic cover with black backing bound to all documents
- cover letter explaining purpose of research and student incentive for participation (see Appendix A)
- student assent form (see Appendix E)
- parent permission form (see Appendix F)
- SEMDIFF instrument (see student attitude toward STEM instrument – initial – Appendix B)
- student attitude toward STEM instrument: initial (see Appendix B)

Located on the front-center of the white envelope was an adhesive label. This label displayed a specific date that indicated the day for which the research packet was to be completed and returned to the homeroom class. The students were offered an incentive for their cooperation and participation with the research study. All students who submitted completed packets were entered into a drawing to receive an assembly of gift cards with a total value of $100. The winning student was provided the additional incentive of deciding which gift cards they preferred.

Data Collection

On Monday, January 26, 2009, a ninth-grade class of 21 students was provided with the research packets during their assigned homeroom period. The researcher handed out the packets to the students while providing verbal instructions regarding the project, the incentive, and the due date. The students were instructed to return the packets to the researcher on Wednesday, January 28, 2009, during the same homeroom period. The date was also provided on the front of the envelope. The ninth-grade students were provided two full days to complete the packet as well as obtain their parents' signatures. On Tuesday, January 27, 2009, a sophomore class of eighteen students was provided the research packets with similar instructions. The students were instructed to return the packets to the researcher on Thursday, January 29, 2009, during the same homeroom period.

On Wednesday, January 28, 2009, a snow storm came through the metropolitan area and forced the local schools to close for the day. This, of course, included the research site for this study. On Thursday, January 29, 2009, the researcher visited both the ninth-grade and tenth-grade homerooms to collect available research packets. The researcher collected eight packets from the ninth-grade homeroom and four packets from the tenth-grade homeroom. Both homerooms were provided an extension to complete the provided research packets due to the storm conditions and the closing of school. On Friday, January 30, 2009, the researcher returned to the high school and collected only two more packets from the sophomore homeroom class bringing the class's total to six. No more additional packets were provided by the ninth-grade students.

On Monday, February 2, 2009, the researcher visited n eleventh-grade class homeroom. Eighteen students received the research packet and were instructed to have it completed and returned by homeroom on Wednesday, February 4, 2009. On Tuesday, February 3, 2009, the researcher visited a twelfth-grade class and distributed 17 research packets. The students were instructed to have the packets ready by Thursday, February 5, 2009. Before leaving the school grounds, the researcher returned to the eleventh-grade class homeroom to remind the students that the packets were due the following morning. On Wednesday, February 4, 2009, the researcher visited the eleventh-grade class homeroom and collected six packets. The researcher offered to return to the eleventh-grade class homeroom on the following day to collect any additional packets that may be available. A collection of students displayed interest in the extension offer by presenting their hands raised. Prior to leaving the school, the research visited the twelfth-grade class homeroom to remind the students that the research packets were due the following morning.

On Thursday, February 5, 2009, the researcher returned to the twelfth-grade class homeroom to collect the available research packets. Ten packets were returned to the researcher. The same offer provided to the eleventh-grade class regarding an extension was presented to the twelfth-grade students. The students did not display any observable interest in the extension offer even after being directed by the researcher. Before leaving the building, the researcher revisited the eleventh-grade homeroom and collected three more research packets, bringing the eleventh-grade class total to nine. Refer to Table 17 for overall data collection numbers and percentages.

Data Analysis

All returned student attitudinal instruments had identifying information that was coded and separated to maintain student response anonymity. All appropriate information was stored in a secure area for later reference if required. The data collected from the instrument was analyzed using SPSS (2009) statistical software, version 17.0. Demographic information was collected and organized in the form of frequency distributions and percentages.

	Data Collection					
Grade Level	Provided	% of School	Returned	%	Completed	%
Ninth	21	22%	8	38%	8	38%
Tenth	18	23%	6	33%	6	33%
Eleventh	18	18%	9	50%	8	44%
Twelfth	17	17%	10	59%	9	53%
Total:	74	20%	33	45%	31	42%

Table 17. Student Attitude Toward STEM – Pilot Study Collection Rates

Principal Components Analysis

The items created for the initial instrument and utilized in the pilot study were analyzed through the application of a principal components analysis. This analysis indicated a number of principal components which accounted for the majority of the variance in the students' responses (Lomax, 2007). It was previously theorized that the four categories of attitude created from the review of research would be identified and reinforced from the principal components upon completion of the analysis. They were predicted to be *awareness, ability, value,* and *commitment* (Objectives #1a and #1b). Three principal components were identified across all four content areas. They were identified as *interest, ability,* and *value* by reviewing the associated items and their respective component loadings. The suggested principal components and their items were subjected to an orthogonal rotation; a process in which “the factors are extracted so that their axes are maintained at 90 degrees. Each factor is independent of, or orthogonal to, all other factors” (Hair, Black, Babin, Anderson, & Tatham, 2006, p. 103).

The purpose of this analysis is to validate the assigned items with the depicted principal components – i.e., discovered attitudinal categories. “[R]otation achieves clarity by seeking factors that result in each item substantially loading on – i.e., correlating with – only one factor” (DeVellis, 2003, p. 121). The items that demonstrated an explicit high loading on each identified principal component – correlations closer to 1.00 – allowed the researcher to identify the natural groupings and appropriately label each principal component.

Cronbach’s Alpha

Once the principal components and corresponding items were identified; they were checked for reliability. This was carried out for each content area of STEM. Cronbach's Alpha is a reliability test used to determine the internal consistency of an instrument. It was administered to determine the proportion of variance among the item scores and the true score for each identified factor (DeVellis, 2003). The higher the value of covariance indicated by a certain item – closer to an alpha of 1.00 – the greater the chance that a specific item is measuring the same construct as the other items included in the instrument. It is recommended that items with covariance values closer to 1.0 – i.e., .70 and above – are to be purposefully selected for future instrument use. Nunnally

(1967) suggested that reliability coefficients between .50 and .60 are adequate in the early stages of research.

Reliability measures for each of the CBAM SoC have been calculated through a series of longitudinal and cross-sectional studies between 1972 and 1976. Reliability varied for each stage of concern; alpha coefficients ranged from .64 to .83 (Hall et al., 1986). However, other studies have provided different results. A 1992 study by Bailey and Palsha reported that their application of the original CBAM SoC questionnaire provided alpha coefficients of .45 to .77 (Bailey & Palsha, 1992).

This same study (Bailey & Palsha, 1992) recommended a shortening of the SoC as well as a decrease in the number of items. Both recommended adjustments increased reliability estimates. For the purposes of this study, it was theorized that the alpha coefficient would be comparable to that of the CBAM instrument (Objective #1c). The desired alpha coefficient was .70 or higher, similar to the average of the mid 70s CBAM study as well as the recommendations of DeVellis (2003).

Pearson Product Moment Correlation

The Pearson product moment correlation is a correlation coefficient procedure that attempts to indicate if there is covariance between two variables. The two variables investigated were the SEMDIFF attitudinal instrument and the student attitude toward STEM instrument. Standard deviations from either instrument were standardized to represent values ranging between -1 and +1. The conversion of scores makes interpretation of a relationship between the two instruments easier to comprehend. A relationship of +1 represents a perfectly positive relationship and a -1 indicates a perfectly negative relationship. A relationship of 0 indicates a lack of linear relationship between the two instruments.

A lack of covariance would indicate that the instruments do not vary together. Such a result could suggest that the attitudinal instrument created within the context of this study does not measure attitude to the same degree as the historically reinforced SEMDIFF instrument. To provide concurrent validity for the student attitude toward STEM instrument, a positive relationship between the two instruments would be required (Objective #1c). Correlations that fall between .35 and .65 – positive or negative – are considered to demonstrate a moderate relationship (Gay et al., 2006). However, "a correlation coefficient much lower than plus or minus .50 is generally useless for either group prediction or individual prediction" (p. 194).

Focus Group

After completing the data analysis with the SPSS software, a focus group of available students was conducted. Packets that were completed and returned to the researcher were compiled by class rank. Random selections from each pile were made by the researcher. Sixteen students' names were drawn from the piles, four from each grade level. On March 11, 2009, students were assembled and interviewed during the first four periods of the school day. Of the 16 that were randomly selected, only 12 students were available on the day of the focus group session. These students were notified during their homeroom periods and study halls to attend the interview session during their assigned study hall times. Announcements were made over the intercom system each period to remind students' notified to attend the session.

The interview sessions were conducted in the school's library and only lasted 40 minutes. Of the 12 available students, 9 students attended the sessions and were interviewed over the duration of the school day. The 9 students consisted of 2 ninth-grade students, 2 tenth-grade students, 1 eleventh-grade student, and 4 twelfth-grade students. The students were interviewed as they became available during the school day. "Reflections on what the [students] say can lead to wholesale changes in the idea of the construct … construct components … specific items … [and] scoring schemes" (Wilson, 2005, p. 57). Students were asked to re-state the items in their own words to demonstrate item clarity and overall instrument communication. This was done to avoid certain aspects of measurement error. Very little direction was provided by the researcher while the students were responding to each item. The students were allowed to discuss each item among themselves until an agreed upon consensus was reached.

The researcher collected notations from the group discussion process, but waited until after the interviews were completed to review the information provided. The students were also asked to assign a numerical value for each of the response choices for each item scale, both for the SEMDIFF and the attitude instrument. This was done purposefully to ensure correct item scaling procedures were utilized by the researcher during the data analysis. It was expected that these steps would provide greater content and face validity in addition to the computer-based data analysis.

Pilot Study Results

Three principal components were identified as a result of the principal components analyses: *interest, ability,* and *value*. Each principal component was represented for each of the STEM content areas. According to the Cronbach's alpha calculations, each identified component indicated very high reliability with alpha ratings above .70. The strong reliability for each principal component would remain consistent for the overall instrument. The complete collection of items used in the pilot study provided very strong alpha ratings for each of the content areas: science = .94, technology = .91, engineering = .93, and mathematics = .96.

The Pearson product moment correlation between the overall SEMDIFF and STEM instruments was .58 (p = .001), indicating a significant, moderately positive relationship between the two instruments. As described earlier, correlations that fall between .35 and .65 are considered to demonstrate a moderate relationship, but coefficients lower that .50 are not considered useful (Gay et al., 2006). Review of the content area correlation coefficients demonstrat a moderately positive relationship for most of the content areas. A moderately positive relationship between the two instruments indicates that their standard deviation vary together and therefore, they are most like measuring similar constructs – in this case, the construct of attitude.

Content areas			Principal components					
	Overall		Interest		Ability		Value	
	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items
Science	.94	29	.94	13	.95	10	.90	7
Technology	.91	34	.77	6	.92	11	.84	8
Engineering	.93	34	.90	13	.90	9	.82	8
Mathematics	.96	34	.76	6	.95	9	.89	7

Table 18. Student Attitude Toward STEM – Cronbach's Alpha Scores

The correlation between the SEMDIFF and STEM instruments for the content area of science was only .46 (p = .013). This measure of the science content area still revealed a moderately positive relationship between the SEMDIFF and the student attitude toward STEM instrument, though less significant than the comparison of the instruments including all content areas. Technology and engineering content areas also demonstrated that coefficients for their content area headings were both moderately positive: technology, r = .41, p = .031, engineering, r = .50, p = .007. The correlation coefficient of mathematics was the only content area to provide a highly positive correlation with a coefficient of .75 (p = .000) (See Appendix H.)

Review of the SEMDIFF provided some insight as to why the correlations between the two instruments were less than anticipated, though still promising. Only two principal components were identified after the review of the SEMDIFF instrument. They were defined as *evaluation* and *physical* principal components based upon review of the bi-polar pairs that were associated with each principal component. The *evaluation* principal component was comprised of the bi-polar pairs including bad-good, like-hate, loathe-welcome, interesting-dull, pleasant-foul, and optimistic-pessimistic. The bi-polar pairs associated with this principal component were created purposively to represent the *evaluative*, *potency*, and *interest* categories as indicated by SEMDIFF research and attitude instrument expectations.

The *physical* principal component was comprised of the bi-polar pairs including complex-simple, easy-hard, hard-soft, and light-heavy. This collection of bi-polar pairs was created to represent both *potency* and *activity/action* categories as indicated by

SEMDIFF research. The two identified principal components were found to exhibit strong reliability as indicated by alpha scores close to or above .70 (refer to Table 19). An exception was demonstrated by the content area of engineering with an overall instrument reliability alpha of .60 and a *physical* principal component alpha of .50. The exception of low reliability for the SEMDIFF for the engineering content area could be caused by lack of student exposure or experience with this content area.

A collection of bi-polar pairs did not display discernable consistency toward either of the identified principal components. These items were reviewed for their bi-polar pair loadings provided by the principal components analysis in addition to comments made by the student focus group. The bi-polar pairs included *feminine-masculine*, *severe-lenient*, *tenacious-yielding*, *active-passive, cold-hot, weak-strong,* and *slow-fast*. *Severe-lenient* and *tenacious-yielding* bi-polar pairs both demonstrated varied item loadings on both principal components for varied content areas. Though the bi-polar pair loadings indicated a concern for their use, it was the review of the focus group and the students' collective perceptions that demonstrated a plausible cause for the varied results resulting from the analysis. The students could not identify the meaning or association of the two bi-polar pairs of *severe-lenient* and *tenacious-yielding* for any of the content areas because they were not familiar with the terms. Specifically, the use of the words "*lenient*" and "*tenacious*" made these bi-polar pairs difficult for the students to comprehend and most likely led to the varied loadings upon the identified principal components.

Content area						
	Principal components					
	Overall		Evaluation		Physical	
	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items
Science	.81	18	.87	8	.72	5
Technology	.84	18	.88	10	.63	7
Engineering	.60*	17*	.84	8	.50	6
Mathematics	.90	18	.94	8	.73	3

*Bi-polar pair removed – weak-strong). Prior to removal, alpha was .54.

Table 19. Semantic Differential – Cronbach's Alpha Scores

The remaining five bi-polar pairs – *cold-hot, active-passive, slow-fast, weak-strong,* and *feminine-masculine* – also demonstrated varied loadings on the identified principal components for each of the content areas. The inconsistency regarding the bi-polar pair loadings led the researcher to question possible complications with the chosen value coding applied to the pairs during the analysis procedure. The focus group was used again to verify the coding implemented for the data analysis process. Students were asked to indicate which of the two terms utilized in the bi-polar pairs demonstrated a stronger or higher value; simply put, which term was worth more to them.

Once the students' supplied an initial response regarding their perceptions of the terms, they again were asked to consider each of the bi-polar pair's terms value while considering a specific content area – either science, technology, engineering, or mathematics. This was carried out for all bi-polar pairs, not just the five sets under review. It was demonstrated by the students' responses that a clear and consistent value could not be established for any of the five bi-polar pairs. It was determined from the students' review that the bi-polar pairs of *feminine-masculine, cold-hot, slow-fast, weak-*

strong, and *active-passive* did not correctly address the content areas and the attitude construct for which they were being used.

The analysis of the SEMDIFF bi-polar pairs indicated that the seven bi-polar pairs of *feminine-masculine, severe-lenient, tenacious-yielding, active-passive, cold-hot, weak-strong* and *slow-fast* may have had an influence upon the SEMDIFF analysis results and therefore have affected the SEMDIFF and STEM instrument correlation. A second correlation was performed using the STEM attitude instrument and the SEMDIFF with the seven bi-polar pairs – as previously indicated – removed from the instrument. The Pearson product moment correlation between the overall modified SEMDIFF and STEM instruments was now .63 (p = .000), indicating a somewhat more significant and moderately positive relationship than the previous score of .58 (p = .001). The correlation between the modified SEMDIFF and STEM instruments for the content area of science only improved the correlation score to .48 (p = .010) from the previous score of .46 (p = .013). This measure still constitutes a moderately positive relationship with a slight improvement in significance.

Technology content area demonstrated a slight but surprising drop in the correlation coefficient score, reporting a correlation of .40 (p = .034) from what was previously a score of .41 (p = .031). Engineering content area demonstrated a much stronger relationship from the previous correlation that provided a score of .50 (p = .007). The use of the modified SEMDIFF allowed for the correlation for engineering to provide a score of .63 (p = .000). Technology and engineering content areas – like the science content area – demonstrated a moderately positive relationship; however, a noticeably stronger, almost highly positive correlation was indicated for the engineering content area. Significance of the correlations improved for these content areas as well, with the exception of the technology content area that demonstrated a slight reduction in statistical significance. The correlation coefficient for the content area of mathematics maintained its highly positive correlation with a coefficient score of .76 ($p = .000$). This improved correlation coefficient was only a small increase from the previous score of .75 ($p = .000$). All of these results are displayed in Appendix H.

The correlation provided an example of concurrent validity for the student attitude toward STEM instrument in its use as a measure of the construct of attitude. The SEMDIFF instrument and its historical implications toward attitudinal measurements made it a plausible comparison model for the correlation analysis. The information demonstrated by the coefficient of correlation between the SEMDIFF (and SEMDIFF modified) and the STEM instruments clearly indicated an overall significant, moderate, and positive relationship thereby providing a strong example of concurrent validity for the student attitude toward STEM instrument (Objective #1c). Given this information, it may be concluded that the student attitudinal instrument toward STEM may contain valid item content for the measurement of the attitude construct. Also, it may be concluded that the student attitude toward STEM instrument is a valid assessment of attitude for each of the STEM content areas.

Of course, the correlation only depicts how well the two implemented instruments shared variance among the analyzed students' responses. The small sample size utilized in the pilot study and the subsequent analysis could limit the generalizablity of the data, even though the majority of correlations were found to be significant. The demonstrated significance increases the probability of the correlation scores to indicate a “true relationship” between the SEMDIFF and the STEM instrument (Gay et al., 2006).

Item analysis. The collection and analysis of the data described in the preceding sections provided the researcher with the following results regarding each attitudinal instrument item. Principal components analysis was applied to item responses for each of the STEM content areas. Eigenvalues above 1 were retained and subjected to orthogonal rotation (see Table 20). Principal component item loadings below .30 were suppressed.

Components	Initial Eigenvalue		Varimax rotation	
	Sum of squares	Variance explained	Sum of squares	Variance explained
Science content area				
1	12.23	41%	7.23	30%
2	5.09	17%	6.67	23%
3	4.17	14%	5.47	19%
Total		72%		72%
Technology content area				
1	11.80	39%	9.32	33%
2	4.32	14%	5.31	17%
3	2.23	7%	3.54	11%
Total		61%		61%
Engineering content area				
1	11.86	38%	8.03	25%
2	4.77	13%	4.38	18%
3	3.02	10%	4.23	18%
Total		61%		61%
Mathematics content area				
1	14.52	48%	6.30	31%
2	3.78	13%	6.12	25%
3	3.67	11%	5.61	17%
Total		73%		73%

Table 20. Principal Components Analysis – Total Variance Explained

Three principal components were identified by the researcher along all content areas: they are labeled as *interest, ability,* and *value*. The items that loaded upon the three identified principal components were not exclusive. Possible inter-correlations between the identified principal components were demonstrated by shared item loadings (see Tables 21- 24). The multiple item loadings were considered during the review and revision of the instrument items. The review of each item is detailed in the following section.

Principal component of interest. The *interest* principal component was comprised of items primarily created for both *awareness* and *commitment* categories. Both of these categories relate to components of *interest,* but it was hoped that each category would be independently identified as a principal component. Analysis of these items revealed some indications of how the two categories and their items inter-correlated and how it could possibly be adjusted. The following items were identified primarily for the principal component of *interest*. Item #1 (*I like to read about:)* indicated an overall high loading on the identified *interest* principal component. This item was designed specifically to indicate an initial level of interest (*awareness category*) regarding each of the four STEM content areas. Item #1 loaded well on the principal component of *interest* for the content areas of science (.71), technology (.77), and mathematics (.69).

Engineering was the only content area for which this item did not identify well with regard to initial interest (.32). The focus group indicated that the low engineering score was possibly due to a lack of exposure to and understanding of engineering, as a course or as a concept.

Items:		Principal components Interest	Ability	Value
1.	I like to read about	.71		
2.	My school offers courses in			
3.	My school does not offer after school programs in			
4.	I enjoy watching TV shows involving	.48		
5.	I do not want to learn more about			
6.	I do not enjoy taking courses in	.57	.36	
7.	Courses in [subject] are available to me			
8.	I dislike the challenge of	.49	.62	
9.	I am good at projects involving	.50	.58	
10.	[subject] is difficult for me		.91	
11.	I perform well in [subject] courses		.83	
12.	I can not handle advanced courses in	.33	.88	
13.	[subject] is simple		.69	
14.	I do not worry about taking tests in		.77	
15.	I struggle in [subject] courses		.93	
16.	I do not understand		.87	
17.	Homework in [subject] is easy		.84	
18.	[subject] is important			.90
19.	What I learn in [subject] has no value to me	.75		
20.	I believe there is a need for			.91
21.	I need	.31		.79
22.	Learning [subject] will not help me	.65		.42
23.	[subject] is good	.63		.52
24.	I care about developments in			.86
25.	[subject] is not worth me time to understand	.36		.57
26.	I would dislike more/advanced courses in	.33		
27.	I would like to participate in more after-school programs in	.71		.31
28.	I am curious about a career involving	.63		
29.	I am interested in advanced programs involving	.77		
30.	I have no interest in discovering new ways to apply	.54	.31	.36
31.	[subject] is not a vital part of my perceived future	.65		
32.	I intend to further develop my abilities in	.68	.51	
33.	I will continue to enjoy the challenge of	.85		
34.	I like	.81		

Table 21. Science Content Area Principal Components Analysis – Pilot Study

Items:	Principal components Interest	Ability	Value
1. I like to read about	.77		
2. My school offers courses in			
3. My school does not offer after school programs in			
4. I enjoy watching TV shows involving	.48		
5. I do not want to learn more about	.60		
6. I do not enjoy taking courses in	.53		
7. Courses in [subject] are available to me			
8. I dislike the challenge of	.74		
9. I am good at projects involving		.53	-.32
10. [subject] is difficult for me	.45	.62	
11. I perform well in [subject] courses		.86	
12. I can not handle advanced courses in		.72	
13. [subject] is simple		.86	
14. I do not worry about taking tests in		.71	
15. I struggle in [subject] courses		.77	
16. I do not understand		.77	.34
17. Homework in [subject] is easy		.87	
18. [subject] is important			.69
19. What I learn in [subject] has no value to me	-.34		.57
20. I believe there is a need for			.86
21. I need			.85
22. Learning [subject] will not help me	.42		.44
23. [subject] is good			.89
24. I care about developments in	.59		
25. [subject] is not worth me time to understand	.36		.57
26. I would dislike more/advanced courses in			.37
27. I would like to participate in more after-school programs in	.58		
28. I am curious about a career involving	.70		
29. I am interested in advanced programs involving	.78		
30. I have no interest in discovering new ways to apply	.49		.61
31. [subject] is not a vital part of my perceived future	.48		.42
32. I intend to further develop my abilities in		.58	
33. I will continue to enjoy the challenge of		.60	.33
34. I like	.58	.52	

Table 22. Technology Content Area Principal Components Analysis – Pilot Study

Items:	Principal components Interest	Ability	Value
1. I like to read about	.32		
2. My school offers courses in			
3. My school does not offer after school programs in			
4. I enjoy watching TV shows involving		.32	.41
5. I do not want to learn more about			
6. I do not enjoy taking courses in	.71	.31	
7. Courses in [subject] are available to me			
8. I dislike the challenge of	.68	.37	
9. I am good at projects involving	.51	.37	
10. [subject] is difficult for me		.69	
11. I perform well in [subject] courses		.91	
12. I can not handle advanced courses in		.78	.45
13. [subject] is simple		.73	
14. I do not worry about taking tests in			
15. I struggle in [subject] courses		.71	.43
16. I do not understand		.69	.47
17. Homework in [subject] is easy		.81	
18. [subject] is important			.75
19. What I learn in [subject] has no value to me	.47		.60
20. I believe there is a need for			.87
21. I need			.92
22. Learning [subject] will not help me	.46		.44
23. [subject] is good	.36		.79
24. I care about developments in	.49		
25. [subject] is not worth me time to understand	.30		.45
26. I would dislike more/advanced courses in	.35	.51	
27. I would like to participate in more after-school programs in			.34
28. I am curious about a career involving	.74		
29. I am interested in advanced programs involving	.64		
30. I have no interest in discovering new ways to apply	.67		
31. [subject] is not a vital part of my perceived future	.67		
32. I intend to further develop my abilities in	.79		
33. I will continue to enjoy the challenge of	.68		
34. I like	.82		

Table 23. Engineering Content Area Principal Components Analysis – Pilot Study

Items:		Principal components Interest	Ability	Value
1.	I like to read about	.69		
2.	My school offers courses in			
3.	My school does not offer after school programs in			
4.	I enjoy watching TV shows involving	.65		
5.	I do not want to learn more about			
6.	I do not enjoy taking courses in	.38	.55	.51
7.	Courses in [subject] are available to me			
8.	I dislike the challenge of		.63	.50
9.	I am good at projects involving	.69	.51	
10.	[subject] is difficult for me		.81	
11.	I perform well in [subject] courses		.77	.33
12.	I can not handle advanced courses in	.57	.67	
13.	[subject] is simple		.81	
14.	I do not worry about taking tests in		.87	
15.	I struggle in [subject] courses	.45	.82	
16.	I do not understand		.77	.40
17.	Homework in [subject] is easy		.80	
18.	[subject] is important			.80
19.	What I learn in [subject] has no value to me			.75
20.	I believe there is a need for			.76
21.	I need			.86
22.	Learning [subject] will not help me	.73		-.43
23.	[subject] is good	.49	.55	.55
24.	I care about developments in	.43	.36	.53
25.	[subject] is not worth me time to understand			.73
26.	I would dislike more/advanced courses in	.67	.44	
27.	I would like to participate in more after-school programs in	.79		
28.	I am curious about a career involving	.78		.36
29.	I am interested in advanced programs involving	.33	.42	.38
30.	I have no interest in discovering new ways to apply	.38		.59
31.	[subject] is not a vital part of my perceived future			.87
32.	I intend to further develop my abilities in			.74
33.	I will continue to enjoy the challenge of	.44	.51	.59
34.	I like	.44	.53	.47

Table 24. Mathematics Content Area Principal Components Analysis – Pilot Study

The focus group and the secondary panel review also suggested the question was too specific. The term “read” as it was used in item #1 could offer an additional component to the overall item that may alter the interpretation. A student may have interest in a certain content area, but may not necessarily have interest in reading about it or reading in general. Students in the focus group suggested that in order for them to read about a content area, a greater amount of interest – i.e., commitment – would be required. This item was reworded to reflect the recommendations of the student focus group and the expert panel in an attempt to better represent initial interest toward STEM (see Appendix G).

Item #4 (*I enjoy watching TV shows involving*:) was developed to indicate an initial level of interest toward STEM. The content area of mathematics was the only content area to provide a clear and concise item loading on the *interest* principal component (.65). Science and technology each displayed acceptable item loadings on the *interest* principal component – science = .48, technology = .48 – but were not as high as anticipated. Item #4 related to the engineering content area did not load on the *interest* principal component, but instead shared the loading between the *ability* (.32) and *value* (.41) principal components.

Like the previous item #1, item #4 results may have been altered by poor item wording. Researcher, expert panel, and focus group review suggest two words as possible item influences, “*watching*” and “*TV*.” “*Watching*” implied an action – or choice of an action) and therefore could explain some of the *ability* principal component loading for the content area of engineering. “*Watching TV*” or simply “*TV*” was suggested by the student focus group to be an entity of value and therefore may cause item loading on that principal component. Also, lack of exposure to the content area of engineering may influence this specific item loading. The low loading for the other content areas of science and technology could also be traced to lack of exposure, specifically the exposure of watching TV related to these content areas. Student interest in watching TV may not be directly related or connected to their interest in the specific content areas. This same issue was discussed after reviewing item #1. Therefore, this item was reworded to better address the intended principal component of initial interest (see Appendix G).

Item #6 (*I do not enjoy taking courses in:)* demonstrated a high *interest* principal component loadings for science (.57), technology (.53), and engineering (.71). However, both science and engineering displayed additional loadings for the *ability* principal component: science = .36, engineering = .31. These loadings were accounted for by the wording of the item itself – citing specifically the term "*taking*." It is the action of "*taking courses*" that may have been influential in the additional item loadings for science and engineering content areas. It may also provide a reason for why the content area of mathematics had an item loading for item #6 that was shared between *ability* (.55), *value* (.51), and *interest* (.38).

Item #8 (*I dislike the challenge of:*) was also intended to indicate initial interest toward the STEM content areas. A divided principal component loading was demonstrated between *ability* and *interest* principal components. Technology (.74) and engineering (.68) content areas both displayed high item loadings on the *interest* principal component. Science (.62) and mathematics (.63) both displayed high item loadings on the *ability* principal component. Almost all content areas had secondary loadings – excluding technology – on additional principal components. Item # 8 for science content area demonstrated an item loading on the *interest* principal component (.49); engineering content area demonstrated item loading on the *ability* principal component (.37); and mathematics content area demonstrated additional item loading on the *value* principal component (.50).

A proposed reasoning for this "split" loading between *interest* and *ability* principal components may again be witnessed by the wording of the item itself. The term "*dislike*" was purposefully used to draw a response by the student related to an *interest* principal component. It is not surprising that the majority of item loading for all content areas – with the exception of mathematics – was on the *interest* principal component. However, the item loading on the *ability* principal component could be influenced by the use of the word "*challenge*" within the item structure. Students may have reacted to the perceived difficulty or ease of the content area – i.e., their own perceived ability – rather than their interest toward the content area. Rewording was recommended for this item prior to implementation in the comparison study (see Appendix G).

The remaining items were created to measure students' commitment toward the STEM content areas. As previously discussed, *commitment* and *awareness* categories were both identified for the *interest* principal component. It was hoped that the items created for the *commitment* category would be independently identified, but as indicated by the pilot study analysis, that was not the case. Review of these items was utilized to address this issue for the comparison study. Item #26 (*I would dislike more/advanced courses in*:) was the first item for the *commitment* category section of the instrument.

The *interest* principal component was indicated by item loadings on the content areas of science (.33), engineering (.35), and mathematics (.67). Technology content demonstrated an item loading only on the principal component of *value* (.37). The *ability* principal component was also displayed though item loadings on engineering (.51) and mathematics (.44) content areas. The analysis indicated that item #26 was not a good indicator of student interest. In fact, the *ability* principal component demonstrated a stronger item loading overall than the *interest* principal component for this item. The focus group proposed that the use of "*more/advanced courses*" in the item may have brought about concerns regarding students' own abilities, therefore increasing the possibility for the *ability* principal component loading. It was suggested that the concept of higher-level learning still be carried through to the comparison study, but in a revised item format (see Appendix G).

Item #27 (*I would like to participate in more after-school programs in*:) was also an item intended to indicate long-term interest toward the content areas. Science (.71), technology (.58), and mathematics (.79) each displayed strong item loadings on the *interest* principal component. The *value* principal component was also demonstrated as having item loadings for science (.31) and engineering (.34) content areas. Item #27 demonstrated some strong item loadings for the *interest* principal component, but lack of experience and/or exposure to after-school programs in general could have altered the results of this item. This could be why the item may have demonstrated item loadings on the *value* principal component for two of the content areas. This item was revised prior to use in the comparison study, but with an intent to maintain the nature of the item (see Appendix G).

Item # 28 (*I am curious about a career involving*:) also attempted to indicate long-term interest toward STEM. This item demonstrated item loadings for the *interest* principal component for all content areas: science (.63), technology (.70), engineering (.74), and mathematics (.78). Only mathematics content area demonstrated a secondary item loading on the principal component of *value* (.36). Item # 28 appeared to be very strong for indicating student interest, particularly for the category of commitment. It was intended to be used in the comparison study with little modification.

Item #29 (*I am interested in advanced programs involving*:) also loaded well on the *interest* principal component for almost all of the content areas of STEM. Science (.77), technology (.78), and engineering (.64) content areas displayed item loadings solely on the *interest* principal component. Mathematics content area also demonstrated item loading on the principal component of *interest* (.33), but it also indicated item loadings on the *ability* (.42) and *value* (.38) principal components. Though, the majority of this item demonstrated strong loadings on the *interest* principal component, the panel of experts recommended rewording of this item. It was thought that the item was too specific through its use of the terms "*advance programs*." They suggested that students may not be aware of the presence of advanced programs at their institution or simply that such programs may not even exist and therefore is beyond the scope of the students' understanding. This item was revised prior to use in the comparison study (see Appendix G).

The principal component of *interest* loaded across all content areas for item #30 (*I have no interest in discovering new ways to apply*:): science (.54), technology (.49), engineering (.67), and mathematics (.38). The principal component of *value* was also indicated by item loadings for the science (.36), technology (.61), and mathematics (.59) content areas. The science content area also demonstrated an additional item loading on the principal component of *ability* (.31). After consultation from both the student focus group and the panel of experts, it was decided to remove this item from the instrument. Many of the students interpreted the item in various ways that correlated with the multiple principal component item loadings. Their collective interpretation of the item would allow the researcher to deem the item confusing and in conflict with the focus of the instrument. The data appears to agree with the students' varied explanations.

Item #31 (*[subject] is not a vital part of my perceived future*:) indicated item loadings on the *interest* principal component across almost all content areas. Science (.65), technology (.48), and engineering (.67) content areas demonstrated item loadings on the *interest* principal component. Technology (.42) and mathematics (.87) content areas also displayed item loadings on the *value* principal component. This division between the item loadings on the *interest* and *value* principal components may be related to the poor wording of the item. Students from the focus group interpreted the item as a value item through use of the statement "*vital part of my perceived future.*" Students saw this portion of the item as having to deal with the weight and worth of the content areas upon their future. Due to this explanation from the students as well as the demonstrated divided item loading, this item was removed from future use in the comparison study.

Item #32 (*I intend to further develop my abilities in*:) only loaded on the *interest* principal component for the content areas of science (.68) and engineering (.79). Science content area displayed an additional item loading on the *ability* principal component (.51). The technology content area demonstrated an item loading only on the *ability* principal component (.58) while mathematics content area only displayed an item loading on the *value* principal component (.74). Many of the students during the focus group sessions demonstrated confusion while attempting to explain the intent and/or understanding of this item. The panel of experts suggested major revision or complete removal of this item prior to construction of the comparison study instrument. The researcher took this information under advisement while revising the item for the instrument used in the comparison study (see Appendix G).

Item #33 (*I will continue to enjoy the challenge of*:) loaded on the *interest* principal component for science (.85), engineering (.68), and mathematics (.44) content areas. The technology content area did not indicate item loading on the *interest* principal component, but did display item loadings on the *ability* (.60) and *value* (.33) principal components. The mathematics content area also displayed additional item loadings on the *ability* (.51) and *value* (.59) principal components. Concerns regarding the use of the word "*challenge*" were cited by the expert panel after reviewing the data analysis. The feedback from the student focus group aligned with the panel of experts recommendations. While reviewing the item, the students indicated varied explanations for the item. Most of the student interpretations focused upon the concept of ability. It was strongly suggested that this item be reworded or simply removed if a better variation could not be achieved for the comparison study. The researcher revised the item for the known-group comparison study.

Item #34 (*I like*:) is an initial interest item that was purposefully placed at the end of the instrument as a summative item for the overall survey. The *interest* principal component was identified by item loadings along all content areas: science (.81), technology (.58), engineering (.82), and mathematics (.44). Additional principal components were also identified for the content areas of technology (*ability* = .52) and mathematics (*ability* = .53, *value* = .47). This item was strongly recommended by the panel of experts to be used in the comparison study, without regard to the item loadings on the identified principal components. It was deemed too strong of an item for the overall construct of attitude to be removed from the study prior to the implementation with a larger sized sample. Therefore, this item was used in the comparison study.

Principal component of ability. The second principal component was identified as *ability*. The items identified within this principal component were collectively the strongest of the three identified principal components as indicated by the analysis. Item #9 (*I am good at projects involving*) displayed a relatively strong loading on the *ability* principal component. Science, technology, engineering, and mathematics content areas displayed the following item loadings on the *ability* principal component: science = .58, technology = .53, engineering = .37, and mathematics = .51. Item #9 also indicated item loadings on the *interest* principal component – science = .50, engineering = .51, mathematics = .69 – and the *value* principal component: technology = -.32. The panel and researcher discussed the unexpected additional item loadings demonstrated by the item analysis. It was decided that use of the term "*projects*" may be too broad, or possibly too specific, of an inference for some students. Rewording of this item was recommended to focus more on perceived ability and less on applications of perceived ability (see Appendix G).

Ability was also indicated as a very strong principal component for item #10 (*[subject] is difficult for me:*). All content areas displayed high item loadings for the *ability* principal component: science = .91, technology = .62, engineering = .69, mathematics = .81. The only secondary loading occurred for the technology content area on the principal component of *interest* (.45). The small sample size could allow for sensitive data analysis. Any outliers present during the analysis could skew the data analysis significantly enough to produce a false interpretation. It may also account for the variation in item loading demonstrated by this item. Focus groups, analysis, and panel review agreed; item #10 was a strong item for indicating students' perceived ability and should remain with little modification.

Item #11 (*I perform well in [subject] courses:*) was another item loading well on the *ability* principal component. Science (.83), technology (.86), engineering (.91), and mathematics (.77) account for the majority of the item loading shown by item #11 on the principal component of *ability*. An exception was found for the content area of mathematics where secondary loading was on the principal component of *value* (.33).

Like the previous item #10; it was decided that this variance in item loading may be due to small sample size sensitivity and the item should not require major modification.

Item #12 (*I can not handle advanced courses in:*) would show what appeared to be another wording concern regarding the overall item. The majority of item loadings was on the *ability* principal component: science = .88, technology = .72, engineering = .78, and mathematics = .67. It is the abundance of secondary item loadings on the principal components of *interest* (science = .33 and mathematics = .57) and *value* (engineering = .45) that revealed concern. Review by the focus group pointed to a possible issue regarding high school student interpretation of the item itself. Two students from the focus group identified what might be considered the interest aspect of the statement by suggesting that "*I can not handle advanced courses*" could easily be interpreted as "*Do I want to handle advanced courses?*" A third student suggested the possible value association by interpreting item #12 as "*Do I need or want advance courses?*" This item was reworded for use in the comparison study (see Appendix G).

Item #13 (*[subject] is simple:*) indicated a very high and consistent item loading on the *ability* principal component across all content areas. Science (.69), technology (.86), engineering (.73), and mathematics (.81) exclusively loaded on the *ability* principal component with no secondary item loadings indicated by the pilot study principal components analysis. Item #13 is a strong item for indicating students' perceived ability toward the STEM content areas and will be used in the comparison study. Item #14 (*I do not worry about taking tests in:*) shares similar characteristics to the previous item #13. Item #14 displayed high item loadings on the *ability* principal component for the science

(.77), technology (.71), and mathematics (.87) content areas. The engineering content area item loading was not reported due to missing student response data. Listwise deletion was implemented by the SPSS software. This item was recommended for use in the comparison study.

Item #15 (*I struggle in [subject] courses*:) indicated high item loadings on the *ability* principal component across all STEM content areas: science = .93, technology = .77, engineering = .71, and mathematics = .82. Additional item loadings on *interest* and *value* principal components were also discovered. The mathematics content area displayed an item loading of .45 on the principal component of *interest* and the engineering content area displayed an item loading of .43 on the principal component of *value*. No specific reasoning regarding the secondary loadings was provided by either the student focus group or expert panel review. Sample sensitivity was proposed as the possible influence for the additional item loadings. However, the overall high item loadings toward the *ability* principal component support the item for further use in the comparison study.

Item #16 (*I do not understand*:) indicated an overall high item loading on the principal component of *ability*: science = .87, technology = .77, engineering = .69, and mathematics = .77. Several additional item loadings were demonstrated. Technology (.34), engineering (.47), and mathematics (.40) content areas each displayed item loadings on the principal component of *value*. Though the overall item loadings were high for the *ability* principal component, the additional item loadings on the *value* principal component did reveal some concern. Some suggestions offered by the student focus group indicated possible issues with interpretations of the item itself. "*I do not understand*" could be interpreted as "*I do not need to understand*." A similar issue was experienced while reviewing item #12. Rewording of this item was taken under consideration prior to implementation in the comparison study (see Appendix G).

Item #17 (*Homework in [subject] is easy:*) indicated a high and consistent item loading on the principal component of *ability* across all content areas. Science (.84), technology (.87), engineering (.81), and mathematics (.80) exclusively loaded on the *ability* principal component with no secondary item loadings indicated by the pilot study principal components analyses results. Item #17 is a strong item, but rewording was suggested for future use by the panel of experts. "*Homework*" was suggested as too specific a concept to be associated with all STEM content areas. All content areas may not assign homework and therefore may limit the universal viability of this item for all STEM content areas. Though this item was very strong for this instrument, rewording was considered and applied for the comparison study (see Appendix G).

Principal component of value. The following items were identified for the *value* principal component. Item #18 (*[subject] is important:*) demonstrated a very high item loading across all content areas on the principal component of *value.* Science (.90), technology (.69), engineering (.75), and mathematics (.80) content areas displayed exclusive item loadings upon the *value* principal component. This item is particularly promising regarding future implementation for the comparison study.

Item #19 (*What I learn in [subject] has no value to me*:) did not perform as well as the previous item. Three of the content areas displayed item loadings on the *value* principal component: technology = .57, engineering = .60, and mathematics = .75. The content area of science did not display an item loading on the *value* principal component while the content area of mathematics was the only content area to depict an independent item loading on the *value* principal component. Additional item loadings were produced for the principal component of *interest*: science = .75, technology = -.34, and engineering = .47. Review of the wording of the item indicated some clear concerns later identified by the focus group of students. The beginning portion of item #19 (*what I learn in [subject]*) presumes that students are interested in learning the content area and therefore may have impacted the principal component identification for this item. Rewording of this item was carried out prior to implementation for the comparison study (see Appendix G).

Item #20 (*I believe there is a need for*:) is another strong item for the principal component of *value*. Science (.91), technology (.86), engineering (.87), and mathematics (.76) content areas each displayed exclusive item loadings on the *value* principal component. The item did not load on any other principal components; therefore, this item will be used in the comparison study with little revision.

Item #21 (*I need*:) shared similar item strength toward the *value* principal component. All content areas produced item loadings on the principal component of *value*: science = .79, technology = .85, engineering = .92, and mathematics = .86. Science (.31) was the only content area to show a secondary item loading on the principal component of *interest*. This small amount of item sensitivity will be considered before the comparison study; however, little change is expected in the item due to its overall *value* principal component strength for each of the content areas (see Appendix G).

Item #23 (*[subject] is good*:) demonstrated item loadings on the *value* principal component for all content areas. However, item loadings for the *value* principal component were only well demonstrated by the content areas of technology (.89) and engineering (.79). Science and mathematics content areas provided item loadings for the *value* principal component that were significantly less: science = .52, mathematics = .55. The content area of mathematics also demonstrated additional item loadings on both the *ability* principal component (.55) and *interest* principal component (.49). Additional item loadings were also displayed by the science and engineering content areas on the *interest* principal component: science = .63, engineering = .36. Reviews by both the student focus group and the panel of experts could not determine any specific reason for the diverse item loadings related to the principal components. The panel of experts strongly suggested that this item should be in the comparison study for its clear association with the construct of attitude.

Item #25 (*[subject] is not worth my time to understand*) identified the principal component of *value* through item loadings for all content areas: science = .57, technology = .57, engineering = .45, mathematics = .73. However, additional item loadings on the principal component of *interest* were also demonstrated by science (.36), technology (.36), and engineering (.30). The student focus group suggested an interpretation of the item that would indicate item wording as a possible explanation for additional principal component loadings. Students indicated that "*worth*" has a strong value relationship, but "*worth my time*" required some level of interest before or beyond establishing a value for a content area. This analysis by the focus group was taken under consideration prior to development and use of the revised instrument (see Appendix G).

Removed items. Some items were removed from the instrument and the associated principal components loadings due to concerns based on the review by the panel of experts, student focus group, and the researcher. Items #2 (*My school offers courses in*:) and #3 (*My school does not offer after-school programs in*:) were both removed from the instrument. Upon review, it was decided that these items were actually demographic in nature and had no indication of measuring the principal component of *interest* or *awareness*. This decision was agreed on by the panel of experts and the researcher prior to data analysis. Item #7 (*courses in [subject] are available to me:)* was also classified as a demographic item and removed from the instrument prior to analysis. Items #2, #3, and #7 have all been included in the revised instrument for the known-group comparison (Phase III) of the research study in the demographic information section and not as part of the instrument itself.

The following items were removed from the item analysis due to their poor or inconsistent loadings on any of the principal components. Item #5 (*I do not want to learn more about*:) was created for the initial interest category of the attitudinal instrument. This item only demonstrated a single *interest* principal component loading for the technology content area (.60). All other content areas demonstrated shared item loadings for all principal components. Therefore, item #5 was determined to be a poor item for the student attitude toward STEM instrument and was removed from the instrument.

Item #22 (*Learning [subject] will not help me*:) demonstrated items loadings on principal components of *interest* and *value* for all content areas. The principal component of *value* was not well supported by item loadings for the content areas of science (.42), technology (.44), engineering (.44), or mathematics (-.43). The principal component of *interest* was only slightly stronger than the *value* principal component as indicated by the item loadings for all STEM content areas: science (.65), technology (.42), engineering (.46), and mathematics (.73). It was concluded that due to poor wording of the item and the overall inconsistent loading across all content areas for the *value* principal component, item #22 would be removed from the instrument and was not utilized for the comparison study.

Item #24 (*I care about developments in:*) was created purposively for the value category of the attitudinal instrument. This item loaded on the *value* principal component for the content areas of science (.86) and mathematics (.53). The principal component of *interest* was indicated by item loadings for the content areas of technology (.59) and engineering (.49). Mathematics also offered additional item loadings on the principal components of *ability* (.36) and *interest* (.43). Item #24 was reviewed and recommended to be revised if not removed completely. The panel of experts and researcher concluded that item #24 was a poor item due to multiple loadings on the principal components anaylsis and specific wording concerns. The focus group of students did identify "*care*" as an element of value; however, it was the specific use of the term "*developments*" that caused confusion with the students' interpretation.

Elements of the removed items were utilized in the revision of the instrument items. Based on this collective item analysis and the intent of the overall instrument, 24 items for each content area were compiled for the revised instrument and used in the comparison study – 96 items total. The 24 items were created to address the four attitudinal categories – awareness, ability, value, and commitment. The principal components analysis indicated three principal components – interest, ability, and value – after review of the initial instrument items. Due to the extensive research conducted – literature review and data analysis – as well as the exploratory nature of this study, the 24 items were revised to address the original four attitudinal categories – awareness, ability, value, and commitment – and not the identified principal components. The researcher did this because the modifications made to the revised instrument items – as indicated by the review of the initial instrument items – may provide different principal components when analyzed with the new sample of students in the STEM-based and college-preparatory high schools.

The small sample size utilized in this phase of the research study was also considered. A small sample size increases the sensitivity of data and thereby could easily influence data analysis results. The researcher revised the instrument based on the results provided by the pilot study analysis, but maintained the initial attitudinal structure based on literature and historical implications. The panel of experts was again contacted and used to review the 24 items for each content area. Corrections were made based on their suggestions and as agreed upon by the researcher (see Table 25). A direct comparison of the items in the two instruments and an explanation of the item revisions are provided in Appendix G.

Category	Associated Items:
Awareness: (Initial Interest)	35. I do not like 36. I enjoy learning about 37. I am curious about 38. I am not interested in 39. I like 40. (subject) is appealing to me
Perceived Ability:	41. (subject) is difficult for me 42. I do well in 43. I am not confident about my work in 44. I have a hard time in 45. Assigned work in (subject) is easy for me 46. I can not figure out
Value:	47. (subject) is important to me 48. I feel there is a need for 49. I do not need 50. It is valuable for me to learn 51. (subject) is good for me 52. I do not care about
Commitment: (Long-term interest)	53. I will continue to enjoy 54. I am not interested in a career involving 55. I am interested in alternative programs in 56. I would like to learn more about 57. I do not wish to continue my education in 58. I am committed to learning

Table 25. Student Attitude Toward STEM – Revised Instrument Items

Phase III: Known-Group Comparison Study

After completing the initial review of the STEM attitude instrument, a *Known-Group Comparison Study* was performed. Two high schools within the local metro area were utilized. One high school consisted of a publicly identified STEM-based program while the other high school consisted of a state-defined college-preparatory program. It was hypothesized that the STEM-based program students would display a stronger interest in STEM, STEM careers, and/or STEM learning practices. The reasoning for this belief is due to the interview and application process students must endure to be accepted into the STEM-based program. To be accepted into the school, a prospective student’s parent/legal guardian must be present during the interview process. The parent and student must sign an agreement to meet the expectations of the school, including polices and learning expectations. These high schools are both located within the local metropolitan area and have established previous associations with the university regarding varied student research projects.

Population

The STEM-based program was operated by a council of the 16 public school districts within the specific county. The council operated the STEM-based program and controlled all financing. Additionally, funding was supplied by the students’ home schools. The STEM-based program held open houses and demonstrations throughout the year to boost public awareness and increase student interest from the outlying school districts. Due to the school’s established recruitment process, the school population provided an opportunity to include a very diverse student body reflective of the overall metropolitan area. The STEM-based program provided education for approximately 300 students as of the 2008-2009 school years. Each year the school accepted a new ninth-grade class of 100 students to commence their STEM education. Since the school has only been in full operation for 3 years, a small student body was available. The anticipated population of the school when full will be a range between 400 and 420 students by 2010.

The comparison high school, a conventional college-preparatory program, was from within the STEM-based school pooling districts and was associated with the supporting council. This high school offered students a college-preparatory curriculum in addition to a variety of alternative education programs. The alternative programs included professional internships at local businesses, local zoo and aquarium experience programs, a teachers' academy, and a career and technical program. The college-preparatory high school's career and technical program was located at a separate location within the district. There are currently three high schools and one technical school within the city's school system. The high school's technology education program covered a wide range of possible curriculum applications, ranging from traditional "shop" learning environments to more contemporary technology and engineering interpretations as defined by ITEA standards documentation (2000). The single high school, the sample of students, and the data collected from the pilot study were not utilized during the analysis for this phase of the study.

Sample

Two grade levels – the ninth and eleventh-grades – from each high school – STEM-based high school and college-preparatory high school – were provided the instrument packets. From the response pool of completed packets – instruments and permission forms – a selection of 100 students was anticipated to be sampled from each grade. Such sampling would allow for approximately 200 packets to be reviewed from each school – an anticipated 400 for the overall study.

The STEM-based high school program only had 92 ninth-grade students available when the instrument packets were distributed. Additionally, the number of available eleventh-grade students was also less than anticipated – consisting of only 78 available students. The reduction in number from the projected 100 available students was credited to a previously undisclosed dropout rate that the school had experienced since opening in the fall of 2006. The college-preparatory high school had a larger number of available students to whom the instrument packets could be distributed: 317 students in the ninth-grade and 292 students in the eleventh-grade. Only 100 students were sought from each of the ninth-and eleventh-grade classes of students. Limitations due to student availability allowed limited direct contact between the researcher and the students. With the assistance of the schools vice-principal, 90 eleventh-grade and 118 ninth-grade students were provided with the instrument packet.

The two high schools collectively provided a sample size of 378 possible participants: 170 from the STEM-based high school and 208 from the college-preparatory high school. As previously stated, Comery suggested at least 200 research participants for an instrument with less than 40 items (as cited in DeVellis, 2003). The sample utilized for this phase of the study intended to address Comery's suggestion and thereby appropriately obtain close to 200 participants for this instrument review.

Research Materials

Every student available to participate in the research study was provided a research packet. Each packet contained the following items:

- Yellow envelope
- Gray cardstock cover page and backing

- Instrument cover page: Revised (see Appendix C)
- Student assent form (see Appendix E)
- Parent permission form (see Appendix F)
- Demographic information section (see student attitude toward STEM instrument – revised – in Appendix D)
- 24 item student attitude toward STEM instrument: Revised (see Appendix D)

Located on the top, left corner of the yellow manila envelope was an adhesive label. This label displayed the department and address from where the instrument was created within the university. This was done to provide credibility to the instrument packet through university association as well as contact information for the students or parents if any questions or concerns were to have risen. The students were offered the same incentive offered to the students during the pilot study. All students who submitted completed packets by the indicated date were entered into a drawing to receive a collection of gift cards with a total value of $100. A completed packet included a signed student assent form, a signed parent permission form, and a completed student attitude toward STEM instrument. This protocol was implemented in both schools used in this phase of the research study. The winning student from each school were provided the additional incentive of deciding which of the gift cards they preferred.

Data Collection

The data collection at the STEM-based high school began on Monday, April 20, 2009. On Monday, April 20, 2009, the students were sent an email from a school administrator informing them of the upcoming research study, its intention, and the student incentive. On Wednesday, April 22, 2009 at 7:55 a.m., 170 instrument packets were distributed to students at the STEM-based high school. An assembly of both eleventh-grade and ninth-grade students were present for morning announcements prior to attending their first period classes. The tenth-grade students were away on a week-long field trip and were not present at the assembly. Also, the STEM-based program did not have a twelfth-grade class at the time of the research study. During the morning announcements, the researcher explained the purpose of the research as well as the incentive available to the students for completing the instrument. The students were instructed to return the instrument packets, completed, on the following school day, Thursday, April 23, 2009. Boxes were left at the front desk of the school for instrument collection along with additional instrument packets. Each box was labeled with either the "junior" or "freshmen" label to aid in the researcher by providing a rough return rate before officially entering the data.

On Thursday, April 23, 2009, the researcher returned to the STEM-based high school to collect completed instruments. The boxes were pulled from the front desk and displayed in front of the students during the morning announcements. Prior to the commencement of the morning announcements, the number of instrument packets in the boxes was counted. Of the 92 provided to the ninth-grade class, only 25 were returned to the researcher. The eleventh-grade class faired much worse with a return of only 13 instrument packets of the provided 78. The students were allowed an additional day to return the instrument packets – completed – into the assigned boxes. They were instructed that the packets had to be returned into the boxes at the front desk by the beginning of school the next day, Friday, April 24, 2009.

On Friday, April 24th, the researcher arrived at the STEM-based high school prior to morning announcements. The collection boxes contained more returned instruments –

36 instrument packets from the ninth-grade class and 22 instrument packets from the eleventh-grade class. Following the morning announcements, the researcher again asked the students to complete and return the instruments by Monday, April 27, 2009. The students were again reminded of the importance of the instrument as well as the student incentive that was still available. The researcher returned again to the STEM-based high school at 11:30 a.m. as suggested by one of the building administrators as a large number of eleventh-grade students would be present and therefore could be contacted directly by the researcher. A collection of 10 eleventh-grade students were identified and reminded of the instrument, its importance, as well as the incentives for them.

On Monday, April 27, 2009, the researcher returned to the STEM-based high school to collect the remaining instrument packets that were submitted. The final collection of instrument packets for the STEM-based high school was 37 from the ninth-grade class and 26 from the eleventh-grade class. Based on the number of packets distributed to the students, the return rate for the ninth-grade class was 40% – 37 instrument packets out of the 92. The return rate for the eleventh-grade class was 33% – 26 instrument packets out of the 78. Additional instrument packets that were not utilized by the students were returned to the researcher by the office staff. Refer to Table 26 for the data collection numbers and percentages.

The data collection began at the college-preparatory high school on Monday, April 20, 2009. On Monday, April 20, 2009 and Tuesday, April 21, 2009, the vice-principal at the college-preparatory high school made an announcement over the intercom system that included an abbreviated statement based on the cover page of the instrument.

He described the intent of the study and made special mention of the student incentive as well as the anticipated return date, Thursday, April 23, 2009. On Wednesday, April 22, 2009, at 11:30 a.m., the researcher arrived at the college-preparatory high school prior to the commencement of seventh period. The vice-principal made an announcement over the intercom system that the research study would be conducted during the next period and for all interested students to be available.

At 11:55 a.m. the bell rang and students began to transition to their seventh period classes. The vice-principal and researcher set up the materials in the cafeteria where most eleventh-grade students would be located. Seventh period was the lunch/free period for both eleventh-grade level and twelfth-grade students. The vice-principal instructed the eleventh-grade and twelfth-grade students to sit on opposite sides of the cafeteria for just the beginning of the lunch period. At 12:10 p.m., the majority of available students had arrived at the cafeteria. This was confirmed by the vice-principal. The researcher explained the research to the eleventh-grade students and distributed the instrument packets. Fifty-two instrument packets were distributed to the eleventh-grade students. Immediately following the distribution of materials to the available eleventh-grade students in the cafeteria, the researcher and vice-principal ascended to the second floor of the high school. The vice-principal indicated that more members of the eleventh-grade class would be available in the school’s library during the seventh period.

On the way to the library, the vice-principal found 4 ninth-grade students. The students were asked to participate in the research study and did so willingly. They received a full explanation regarding the research study and the expected return date.

Upon arrival in the school's library, 15 more eleventh-grade students were found and provided with the instrument packet along with appropriate directions and incentives. The ninth-grade study halls were visited next. Ninth-grade students were primarily located in assigned study halls during the seventh period. Six ninth-grade study halls were visited during the seventh period. Each study hall contained an average of 25 students. The researcher explained the purpose, incentives, and expectations of the research study to each of the six study halls. In all, 118 instrument packets were provided to the ninth-grade class at the college-preparatory high school.

At 12:31 p.m., the vice-principal and researcher returned to the main office. The vice-principal made a second announcement to the students over the intercom system. He instructed any students from the eleventh-grade class who were interested in participating in the research study and the available incentive to report to the office conference room. Twelve students arrived in the office to receive the instrument packets and associated instructions. While explaining and distributing the instrument packets, the eighth period bell had rung for the commencement of classes. The vice-principal instructed the students to use the instrument packets as a pass to return to class. Shortly after, he made an announcement over the intercom system to inform the teachers of the newly assigned value attributed to the instrument packets.

Like the STEM-based high school, two boxes were placed on display in the main office to allow students to return the packets at any time during the following school day. While setting up the boxes, a class of eleventh-grade students was ushered in by the vice-principal. The study hall of eleventh-grade students had assembled in the cafeteria and the vice-principal took advantage of their availability. Eleven more instrument packets were distributed to the eleventh-grade class. In all, 90 instrument packets were provided to the eleventh-grade class at the college-preparatory high school.

The researcher arrived at the college-preparatory high school just before noon on Thursday, April 23, 2009. Again, the vice-principal escorted the researcher to the cafeteria, library, ninth-grade study halls, and finally back to the main office. Prior to performing the “collection march,” the vice-principal made an announcement over the intercom system that he and the researcher would be coming around the school to collect the instrument packets. After completing the trip, 25 eleventh-grade students and 44 ninth-grade students had returned the instrument packets to the researcher. Once back in the main office, the vice-principal informed the students that they had an additional day to return the instruments. They were instructed to return the instrument packets to the main office by the end of the next school day, Friday, April 24, 2009. This same instruction was provided to each collection of students that the vice-principal and the researcher encountered while collecting the initial set of instrument packets.

On Friday, April 24, 2009, at 2:15 p.m., the researcher arrived at the college-preparatory high school to obtain the instrument collection boxes. The vice-principal made an announcement to the school over the intercom system. He instructed all students who had a completed instrument packet to submit it to the main office before leaving the school. At 3:00 p.m. all buses had pulled away from the school and a final count was made of the instrument collection. A total of 52 ninth-grade students and 36 eleventh-grade students submitted instrument packets to the main office by the close of school on

Friday, April 24, 2009. Based on the number of packets provided to the students, the return rate for the ninth-grade class was 44% – 52 instrument packets from the initial 118 that were distributed. The return rate for the eleventh-grade class was 40% – 36 instrument packets from the 90 that were distributed. Refer to Table 26 for the data collection numbers and percentages.

School	Grade Level	Distrib.	% of Pop.	Returned	%	Completed	%
STEM-based high school	Ninth	92	100%	37	40%	35	38%
	Eleventh	78	100%	26	33%	26	33%
Total		170		63		61	
College-preparatory high school	Ninth	118	37%	52	44%	48	41%
	Eleventh	90	31%	36	40%	35	39%
Total		208		88		83	
	Total:	378		151	40%	144	38%

Table 26. Student Attitude Toward STEM – Known Group Comparison Collection Rate

Data Analysis

The surveys were numbered and all identifying items linking the students to the responses on the instrument were removed. A second principal components analysis was preformed for the main study. This analysis focused on the changes in items and the overall instrument as determined from the results of the pilot study. It was anticipated that the same three principal components – interest, ability, and value – would again be identified through the analysis as they were indicated by the pilot study and the review of researcher (Objective #1a and #1b). Internal reliability was again estimated through the use of Cronbach's alpha coefficient. As in the pilot study, an alpha coefficient of .70 or higher was anticipated for the revised instrument (Objective #1c).

Following the item analysis, a known-group comparison was used to establish construct validity. These analyses were preformed to indicate how well the student attitudinal instrument discriminated between the different high school group of interest. It was hypothesized that students enrolled in the STEM-based high school program would exhibit a more positive attitudes toward STEM when compared to students in a conventional college-preparatory high school program (Objective #2a, Hypothesis A). It was also hypothesized that students exposed to STEM education for a longer period of time would exhibit a more positive attitude toward STEM than students who were just entering the program (Objective #2b, Hypothesis B). Lastly, it was hypothesized that male students would exhibit a more positive attitude toward STEM than female students (Objective #2c, Hypothesis C).

To analyze the data, a multivariate analysis of variance (MANOVA) was utilized. The MANOVA is an extension of the analysis of variance (ANOVA). The ANOVA is used to detect group differences on a single dependent variable, but is not capable of measuring multiple dependent variables. The use of the MANOVA was to detect differences between the sample mean scores among a collection of independent and dependent variables (Field, 2005, Lomax, 2007).

Multiple individual ANOVAs could have been utilized, but doing so would increase the familywise error rate and thereby increase the possibility of performing a Type I error (Field, 2005). A Type I error occurs when the researcher concludes there is a significant effect – as indicated by an analyses – but in reality, no significance between the group mean scores exists. Also, the MANOVA procedure has the power to detect whether groups vary along the combination of independent variables. Though it is not the intention of this study to review combinations of the independent variables – school, grade level, and gender – and their possible interactions, information provided from the analyses were utilized to aid in the creation of implications for future research and study.

The MANOVA analysis still provided a univariate analysis for each of the independent variables regarding each of the groups: school, grade level, and gender. Non-parametric analyses were also conducted. Any significance discovered between the intended groups will be checked between the two measures. This additional step should account for any violations regarding statistical assumptions. Assumptions regarding homogeneity of variance and normality were also statistically reviewed. The Levene's test was utilized to establish homogeneity of variance and the Kolmogorov-Smirnov, Shapiro-Wilk, and Kruskal-Wallis were utilized to establish normality – parametric and non-parametric.

Validity

To validate the student attitude toward STEM instrument, three types of validity measures were utilized. They were content validity, face validity, construct validity, and concurrent validity (Cronbach & Meehl, 1955; DeVellis, 2003). “Validity is the most important consideration in developing and evaluating measuring instruments” (Ary et al., 2006, p. 243). Content and face validity were established by the utilization of a panel of experts and a student focus group. Content validity is the “extent to which a specific set of items reflects a content domain” (DeVellis, 2003, p. 49). The experts that freely volunteered to contribute to the research study were representative professionals of their fields. All of the content areas of STEM were represented properly by the participating experts. Their collective insight was attributed to the original 34 items for each content area (see Table 16) and their later approval of the refined 24 items for each content area (see Table 26). Any modifications made by the researcher to the items (see Appendix G) and the overall instrument were approved by the panel prior to student exposure and completion.

The student focus group also provided validity by offering their interpretations of the items. These students represented the age and gender of the population for which the instrument was intended. Their insight was vital to establishing item face validity so that the created items would be better understood by high school students. Clear and concise communication to the intended population is one of the primary goals when constructing a measurement instrument, especially when attempting to indicate a student’s attitude toward a specific content area.

Content validity was enhanced by the literature reviewed during this research project. The CBAM, TEOII, and SEMDIFF materials, along with their historical development and documented validity and credibility, provided a strong foundation for the construction and validation of the student attitude toward STEM instrument. The literature and previous instruments were used to establish attitudinal categories to represent the overall construct of attitude. The created categories were used by the researcher and the panel of experts to develop the instrument's items (refer to Table 16).

An initial form of construct validity, concurrent validity was established through application of the Pearson product moment correlation procedure and its inferences between student responses on the student attitude toward STEM instrument and student responses on the SEMDIFF attitudinal instrument. Concurrent validity is one of two forms of criterion-related validity. The purpose of concurrent validity is to compare two scores obtained at the same time. This was done using two measurement devices; the student attitude toward STEM instrument and the SEMDIFF attitudinal instrument.

The SEMDIFF provided a well-recognized attitudinal instrument from which to compare the overall mean scores for each content area. The SEMDIFF was constructed from bi-polar pairs provided by the established research of Osgood and his associates. Bi-polar pairs were also created that reflected the attitudinal categories created for the attitudinal instrument. The panel of experts reviewed and approved the SEMDIFF before it was implemented (refer to Figure 5).

Even though the individual categories of the SEMDIFF did not directly correlate with the assigned categories of the attitudinal instrument, both instruments attempted to measure student attitude toward STEM. It was this overall attitude correlation – per content area – that was of interest and importance for the concurrent validity sought in this portion of the research study. As demonstrated in Appendix H, a significant and moderately positive correlation was found between the SEMDIFF and the attitudinal instrument as indicated by the Pearson product moment correlation.

The example of concurrent validity provided by the results of the Pearson product moment correlation only applies to the student attitude toward STEM instrument used in the pilot study (Phase II). The indication of concurrent validity does not carry over to the known-group comparison study due to the revisions made to the student attitude toward STEM instrument for the primary study (Phase III). Future studies will provide contemporary examples of concurrent validity for the revised instrument. Another form of criterion-related validity is predictive validity. Predictive validity is determined by comparing scores achieved via an instrument at two different time intervals. This form of validity is typically utilized in longitudinal studies and was not viable for this study given the time frame allotted for the research study.

"Construct validity is concerned with the theoretical relationship of a variable to other variables" (DeVellis, 2003, p. 53). The variables in the case of this study were the overall attitude measurement of attitude, and its associated levels of interest, ability, and value, in relationship to students' current high school and grade level (Hypotheses A and B). The known-group comparison was intended to further develop the construct validity of the student attitude toward STEM instrument by examining the mean scores of these variables and attribute any possible significance to them, collectively or individually

(Cronbach & Meehl, 1955). It is hoped that the collected analysis provided by the extensive attitudinal research, panel of experts, student focus group, principal components analysis, MANOVA, and Pearson product moment correlation would provide an overall collection of data that would indicate a strong example of construct validity for this instrument.

Reliability

An instrument is deemed reliable if it is capable of consistently producing results while controlling for random error (Ary et al., 2006). Internal-consistency procedures were utilized to establish reliability for the student attitude toward STEM instrument. Test-retest reliability was not an applicable procedure due to the time frame allotted for the research study. However, this procedure may be utilized in future applications of this instrument as it is further revised.

The equivalent-forms reliability procedure was also not sought for this research study. This procedure provides the students with two forms of a single instrument. The two forms may vary in item wording or simple format. The concept is to determine if the student responses toward a specific construct are maintained across varying items and instruments. It also may provide a test-retest coefficient depending on the amount of time that has lapsed between testing. During the course of this study, the instrument was still in the process of being developed. If the instrument had more substantial research already conducted, then an alternative form of the instrument could have been produced and administered. One could argue that the multiple content areas reviewed within the research study could provide an applicable format for an equivalent-forms procedure.

However, until the conclusion of this study, the researcher was not able to determine how reliable or valid the items were for any of the content areas, let alone the construct of attitude. Again, this reliability procedure may be applied to future research to aid in establishing greater reliability for this instrument.

Of the internal-consistency procedures, the Cronbach's alpha reliability procedure was chosen. This procedure was chosen specifically for its usefulness for attitudinal scales (Ary et al., 2006). The Kuder-Richardson procedure is utilized for dichotomous data – typically in the form of true/false or yes/no items. This procedure did not fit the intention of the instrument and therefore was not utilized. However, if dichotomous data were to arise during the reliability analysis, it has been suggested that Cronbach's alpha provides results similar to the Kuder-Richarson procedure (Ary et al., 2006).

As indicated previously, the Cronbach's alpha ranges in score value from 0 to 1. The higher the value of covariance indicated by a certain item – closer to an alpha of 1.00 – the greater the chance that a specific item is measuring the same construct as the other items included in the instrument. Items with covariance values closer to 1.0 – i.e., .70 and above – exhibit an acceptable reliability coefficient for internal consistency.
As mentioned previously, Nunnally (1967) suggested that reliability coefficients between .50 and .60 are adequate in the early stages of research. All data was processed by SPSS v. 17.0 software (2009), which has a coefficient alpha as the index of reliability.

Chapter 3 Summary

In chapter 3, content and face validity was established through the use of a panel of experts that were proficient in STEM and STEM education content areas. Also, a student focus group was utilized to represent the population for which the attitudinal instrument was intended. Initial construct validity was established by the implementation of a principal components analysis of the pilot study data. Three principal components were identified – labeled as interest, ability, and value by their associated high loading items. These principal components agreed with the projected attitudinal categories developed from the extensive review of literature. Each principal component displayed high internal reliability as demonstrated by Cronbach's alpha coefficients.

Concurrent validity was established by the application of the Pearson product moment correlation between the student attitude toward STEM instrument and the SEMDIFF attitudinal instrument. The student attitude toward STEM instrument demonstrated a moderately positive relationship to the SEMDIFF and was significant across all content areas. This significant example of concurrent validity is only applicable to the student attitude toward STEM instrument used during the pilot study – prior to revisions. Chapter 4 provides and explains in greater depth the analyses preformed for the main research study (Phase III) using the revised instrument and the known-group comparison.

CHAPTER 4: DATA ANALYSIS

Chapter 4 includes the methods and procedures used to review the revised student attitude toward STEM instrument. The revisions to the instrument were made after a preliminary pilot study was conducted. Initial item analysis in addition to a review by both a panel of experts and a student focus group suggested the applied revisions to the instrument. Each of the analysis procedures is described within the pilot study data analysis in chapter 3.

The final phase – Phase III – of the research study was implemented in two high schools that were anticipated to represent varying educational environments. A second item analysis was performed due to the changes and alterations made to the initial instrument following the pilot study results in chapter 3. Principal components analyses and Cronbach's alpha procedures were performed to extend findings from the previous chapter. Additional procedures were conducted to further establish construct validity for the student attitude toward STEM instrument. These additional analyses included frequency distributions, mean score comparisons, multivariate analysis, and parametric and non-parametric univariate analysis procedures. A review of the objectives and hypotheses as represented by the findings of the analyses conclude the chapter.

Item Analysis

After collecting all available instruments from both the STEM-based and college-preparatory high schools, the completed surveys were numbered, coded, and prepared for data analysis. Table 27 describes the distribution of participants by school, grade, and gender in the known-group comparison sample. Figure 6 illustrates a visual depiction of this same distribution.

	STEM-based high school		College-preparatory high school		
	Females	Males	Females	Males	Total
Ninth-grade	17	18	20	28	83
Eleventh-grade	14	12	22	13	61
Total	31	30	42	41	144

Table 27. Distribution of Gender and Grade Level by High School in the Data Analysis Sample

A second principal components analysis was performed. The principal components analysis was utilized to address the first two parts of Objective #1. This application of the principal components analysis was required due to the revisions of the instrument and instrument items as determined from the results of the pilot study. Eigenvalues above 1 were retained and subjected to orthogonal rotation (see Table 28). Principal components analysis loadings below .40 were suppressed. Three principal components were identified by the researcher for all content areas: *interest, ability,* and *value*.

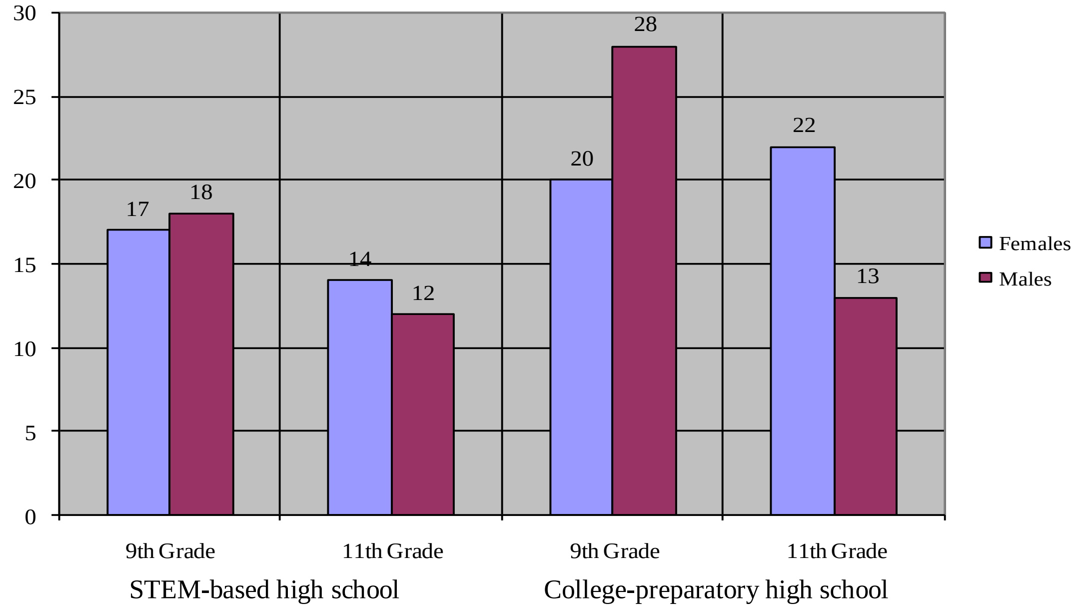


Figure 6. *Distribution of Gender and Grade Level by High School in the Data Analysis Sample*

The three principal components were consistently indicated by both applications of the principal components analyses – the pilot study and the known-group comparison study (Objective #1a). A high percentage of variance was explained by the three identified principal components for each content area: science = 69%, technology = 64%, engineering = 73%, and mathematics = 68%.

Possible inter-correlations between the identified principal components were demonstrated by shared item loadings (see Tables 29 - 32). Each item was reviewed by the researcher and assigned to one of the three identified principal components. Item loadings for all content areas and initial item design intentions were considered prior to principal component assignment. The possibility of inter-correlations between principal components was momentarily overlooked so that further statistical analysis could be performed. Future studies with larger samples sizes and a refined student attitude toward STEM instrument will appropriately address this concern.

Component	Initial Eigenvalue		Varimax rotation	
	Sum of squares	Variance explained	Sum of squares	Variance explained
Science content area				
1	13.47	56%	7.29	30%
2	1.94	8%	5.25	22%
3	1.30	5%	4.14	17%
Total		69%		69%
Technology content area				
1	11.83	49%	5.46	23%
2	2.41	10%	5.24	22%
3	1.22	5%	4.76	19%
Total		64%		64%
Engineering content area				
1	14.20	59%	6.98	29%
2	1.91	8%	5.22	23%
3	1.31	6%	5.21	21%
Total		73%		73%
Mathematics content area				
1	12.95	54%	5.83	24%
2	2.33	10%	5.36	22%
3	1.03	4%	5.12	22%
Total		68%		68%

Table 28. Principal Components Analysis – Total Variance Explained

Items #1 through #6 indicated relatively consistent and high item loadings for the *interest* principal component for all content areas of STEM (see Tables 29 - 32). These items were created to measure initial interest – *awareness* category. Items # 19, #20, and #21 that were created for the *commitment* category – long-term interest – also indicated high item loadings for the *interest* principal component (see Tables 29 - 32). A similar condition was experienced during the preceding pilot study with regard to the *commitment* category. The researcher and the panel of experts discussed the situation and concluded that attempting to delineate between two levels of a singular component this early in the instrument development process may not be a realistic venture. Therefore, the analyses utilized for the known-group comparison was represented by the principal components of *interest, ability,* and *value* identified through examination and attribution of high loading items for all content areas (see Tables 29 - 32).

	Principal components		
Items:	Interest	Ability	Value
59. I do not like	.77		
60. I enjoy learning about	.74	.49	
61. I am curious about	.66		
62. I am not interested in	.72		
63. I like	.73	.49	
64. (subject) is appealing to me	.70	.46	
65. (subject) is difficult for me		.75	
66. I do well in		.69	
67. I am not confident about my work in		.61	
68. I have a hard time in		.80	
69. Assigned work in (subject) is easy for me		.81	
70. I can not figure out		.77	
71. (subject) is important to me	.57		.45
72. I feel there is a need for			.67
73. I do not need			.79
74. It is valuable for me to learn			.77
75. (subject) is good for me			.70
76. I do not care about	.63		.47
77. I will continue to enjoy	.71		
78. I am not interested in a career involving	.75		
79. I am interested in alternative programs in	.61		
80. I would like to learn more about			
81. I do not wish to continue my education in	.56		.59
82. I am committed to learning	.54		.59

Table 29. Science Content Area Principal Components Analysis

Items:	Principal components Interest	 Ability	 Value
1. I do not like	.60	.48	
2. I enjoy learning about	.73	.41	
3. I am curious about	.79		
4. I am not interested in	.71		
5. I like	.78		
6. (subject) is appealing to me	.79		
7. (subject) is difficult for me		.72	
8. I do well in		.63	
9. I am not confident about my work in		.76	
10. I have a hard time in		.80	
11. Assigned work in (subject) is easy for me		.70	
12. I can not figure out		.79	
13. (subject) is important to me			.61
14. I feel there is a need for	.46		.74
15. I do not need			.83
16. It is valuable for me to learn			.74
17. (subject) is good for me	.46	.48	
18. I do not care about	.46		.54
19. I will continue to enjoy	.55	.54	
20. I am not interested in a career involving	.55		
21. I am interested in alternative programs in	.51		
22. I would like to learn more about			
23. I do not wish to continue my education in			.73
24. I am committed to learning	.46		.52

Table 30. Technology Content Area Principal Components Analysis

Items that demonstrated high loadings for the *interest* principal component also displayed additional item loadings for other principal components. Item #1 (*I do not like*) displayed an additional principal component loading for the *ability* principal component (.48). This loading was only provided for the content area of technology and was deemed to have little impact on the overall instrument. Item #2 (*I enjoy learning about*) also displayed additional principal component loading for the *ability* principal component, but this occurred for the content areas of science (.49) and technology (.41). Item #4 (*I am not interested in*) loaded on the *ability* principal component for the engineering content area (.43).

Analyses of items #5 (*I like*) and #6 (*(subject) is appealing to me)* both shared additional item loadings for the *ability* component for the science content area (item #5 = .49 and item #6 = .46). Item #5 also loaded on the *ability* principal component for the content area of mathematics (.41). Each of these additional item loadings on other principal components was not strong or consistent enough to deem major revisions to the items at this phase of the research study. Future research applications and review of this instrument will address these concerns, particularly when a larger sample size is available.

	Principal components		
Items:	Interest	Ability	Value
1. I do not like	.66	.48	
2. I enjoy learning about	.76		
3. I am curious about	.78		
4. I am not interested in	.70	.43	
5. I like	.81		
6. (subject) is appealing to me	.78		
7. (subject) is difficult for me		.77	
8. I do well in	.52	.55	
9. I am not confident about my work in		.74	
10. I have a hard time in		.82	
11. Assigned work in (subject) is easy for me		.71	
12. I can not figure out		.77	
13. (subject) is important to me	.56		.56
14. I feel there is a need for			.79
15. I do not need			.85
16. It is valuable for me to learn			.79
17. (subject) is good for me			.71
18. I do not care about			.71
19. I will continue to enjoy	.59	.47	.45
20. I am not interested in a career involving	.61		
21. I am interested in alternative programs in	.64		
22. I would like to learn more about			
23. I do not wish to continue my education in	.44		.69
24. I am committed to learning	.58		.59

Table 31. Engineering Content Area Principal Components Analysis

Items:	Principal components Interest	Ability	Value
1. I do not like	.71		
2. I enjoy learning about	.78		
3. I am curious about	.67		
4. I am not interested in	.61		
5. I like	.77	.41	
6. (subject) is appealing to me	.74		
7. (subject) is difficult for me		.83	
8. I do well in	.49	.57	
9. I am not confident about my work in		.73	
10. I have a hard time in		.84	
11. Assigned work in (subject) is easy for me		.71	
12. I can not figure out		.79	
13. (subject) is important to me	.50		.56
14. I feel there is a need for			.70
15. I do not need			.83
16. It is valuable for me to learn			.71
17. (subject) is good for me	.47		.55
18. I do not care about			.53
19. I will continue to enjoy	.67	.41	
20. I am not interested in a career involving	.58		
21. I am interested in alternative programs in	.73		
22. I would like to learn more about			
23. I do not wish to continue my education in	.43		.49
24. I am committed to learning	.48		.54

Table 32. Mathematics Content Area Principal Components Analysis

Analysis of item #19 (I will continue to enjoy) was the only item on the *interest* principal component – originally created for the commitment category – that demonstrated item loadings on other identified principal components. Item #19 displayed three additional item loadings on the *ability* principal component for the content areas of technology (.54), engineering (.47), and mathematics (.41). Also, the *value* principal component demonstrated item loading for item #19 for the content area of engineering (.45). The additional loadings for item #19 may be credited to the original intent of the item. The use of the word “continue” suggests that the students have been exposed to the content previously. If the students have not experienced the content area, they would be unaware of their "continued" enjoyment or *interest* toward a specific content area. Therefore, this item may be revised prior to future implementations of this instrument, but for the purposes of this study, its strong identification with the *interest* principal component suggested its use in the comparison analyses.

Items #7 through #12 indicated high loadings for the *ability* principal component for all content areas (see Table 29 - 32). Each of these items was created specifically for the *perceived ability* category. A similar result was revealed during the preceding pilot study. The analysis revealed only one item – item #8 (*I do well in*) – that showed additional item loadings for the *interest* principal component. *Interest* principal component loadings for item #8 were for the content areas of engineering (.52) and mathematics (.49). This item was modified from its original wording that was utilized in the pilot study because of recommendations provided by the student focus group and the panel of experts. The original item – item #11, *I perform well in* – will most likely be re-applied to the instrument following this research study because of its stronger and more concise principal component loading for *ability* – science = .83, technology = .86, engineering = .91, and mathematics = .77. However, for the purposes of the comparison analyses, this item will be included in the *ability* principal component.

Items #13 through #18 indicated high item loadings for the *value* principal component for most content areas (see Tables 29 - 32). These items were created specifically for the *value* category. Additional item loadings were demonstrated for the *interest* principal component for most content areas. Item #13 ([subject] is important to me) loaded on the *interest* principal component for all content areas: science (.57), technology (.46), engineering (.56), and mathematics (.50). The researcher reviewed the shared item loadings demonstrated by item #13 and determined that the scores associated with this item would remain with the *value* principal component for the remainder of the analyses. Future research with larger and diverse samples will be utilized to modify the item as needed.

Item #17([subject] is good for me) provided reasonable item loadings on the *value* principal component for all content areas with the exception of the technology content area. Item #17 displayed item loadings for the *interest* and the *ability* principal components for the technology content area – *interest* = .46, *ability* = .48. Also, for the mathematics content area, an additional item loading was displayed on the *interest* principal component (.47). Item #18 (I do not care about) also demonstrated item loadings on the *interest* principal component for the content areas of science (.63) and technology (.46).

Items that were created for the *commitment* category (long-term interest) also indicated high loadings for the *value* principal component – items # 23 and #24 (see Tables 29 - 32). A similar condition was demonstrated by the preceding pilot study with regard to the commitment category. Item #23 (I do not wish to continue my education in) loaded reasonably well for the *value* principal component for the content areas of STEM. Item #23 demonstrated additional item loadings for the *interest* principal component – science = .56, engineering = .44, and mathematics = .43 – but they were not as strong as those demonstrated for the *value* principal component as determined by the researcher (see Tables 29 - 32). Initial review of this item indicates that it may be interpreted by students for either the *value* or *interest* categories. A student may not find additional educational opportunities in the STEM content areas as important or valuable to themselves. The students may also not be interested in additional education opportunities in the STEM content areas. Revision of this item is expected prior to future research.

Item #24 (I am committed to learning) shared similar results to that of item #23. Item #24 did demonstrate additional item loadings for the *interest* principal component for all content areas: science (.54), technology (.46), engineering (.58), and mathematics (.48). The overall item loadings were still higher on the *value* principal component, but only by a slight margin (see Tables 29 - 32). Like item #23, item #24 could be interpreted for either the *value* or *interest* category. Revision of this item is expected prior to future research.

After review of both item analyses (Phase II and Phase III), it is apparent that *interest, ability,* and *value* principal components share similar interpretive characteristics and that the combination of item wording and student interpretation is critical for any plausible differentiation between the attitudinal components – if such differentiation can be established. This concern was broached during the pilot study and the item analysis that followed. It was anticipated that the revised instrument and instrument items would provide more reliable item loadings on the identified principal components. The researcher felt that although the revised instrument and instrument items demonstrated and overall improvement when compared to the pilot study instrument, further review of the instrument and research is necessary. Additional variables not measured nor analyzed as yet could provide potential reasons and recommendations for instrument item structure and development that could lead to a more reliable and valid instrument.

One item from the revised instrument was removed due to observed threats to reliability and validity. Item #22 (I would like to learn more about) was removed from the Phase III data analysis. Principal components analysis in Phase III revealed inconsistent item loadings for all identified principal components and content areas. Additionally, Cronbach's alpha scores indicated that this item was a threat to reliability, lowering some content alpha scores to below .70. For the remainder of the data analysis, the three researcher identified principal components were used. The principal component of *interest* was comprised of items #1 – #6 and items #19 - #21. The principal component of *ability* was comprised of items #7 - #12. Lastly, the principal component of *value* was comprised of items #13 - #18, #23, and #24.

Internal reliability was again estimated though the use of Cronbach's alpha internal consistency coefficient. This procedure was utilized to reinforce the previous high reliability coefficient established during the analyses in the pilot study. Both applications of Cronbach's alpha address the expectations of Objective #1c regarding instrument reliability. As in the pilot study, an alpha coefficient of .70 or higher was anticipated for the revised instrument. Cronbach's alpha calculations indicate that each identified principal component indicated very high reliability with alpha ratings above .70. The strong reliability for each principal component would remain consistent for the overall instrument. The complete collection of items used in the pilot study provided very strong alpha ratings for each of the content areas: science (.96), technology (.95), engineering (.97), and mathematics (.96).

Content	Overall		Principal components					
			Interest		Ability		Value	
	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items
Science	.96	23	.95	9	.90	6	.91	8
Technology	.95	23	.93	9	.88	6	.90	8
Engineering	.97	23	.95	9	.90	6	.94	8
Mathematics	.96	23	.94	9	.91	6	.91	8

Note. Item 22 was removed from the analysis resulting in an overall total of 23 items

Table 33. Student Attitude Toward STEM – Cronbach's Alpha Scores

The dependent variables were identified through the principal components analysis as *interest*, *ability*, and *value*. These dependent variables are in agreement with the previous principal components analysis provided by the pilot study sample as well as the extensive review of literature regarding the construct of attitude. Internal reliability was also very strong as indicated by the Cronbach's alpha scores exceeding the .70 requirement (Objective #1c).

Independent Variable Analysis

The following sections are comprised of comparisons that reviewed selected independent variables of particular concern. The following analyses were performed to aid in the collective support and refinement of the student attitude toward STEM instrument (Objective #2). Each independent variable reviewed addresses a research hypothesis specific to the study. An accepted hypothesis would provide an example of construct validity for the student attitude toward STEM instrument.

High School Environment – School

It was hypothesized that students enrolled in a STEM-based college preparatory program will exhibit a more positive attitude toward STEM than students enrolled in a conventional college-preparatory program (Hypothesis A, H_1a). The reasoning for this hypothesis was directly related to the content areas focused on by the student attitude toward STEM instrument; these are the content areas of science, technology, engineering, and mathematics. The STEM-based high school was created specifically to promote the development of STEM skills and abilities for interested students. The students attending the STEM-based high school were collected from an assembly of high schools within the immediate metropolitan area.

The high schools were members of an educational council created as both a source of support and administration for the STEM-based high school. The comparison high school was a college-preparatory high school that is a member of the educational council. The students of the college-preparatory high school had an equal opportunity to apply to and, thereby, attend the STEM-based high school if they were so inclined. Therefore, the samples obtained from these two high schools should provide a measureable and statistically significant difference for the student attitude toward STEM instrument. It was only natural to assume that the STEM-based high school students would provide a more positive attitude toward STEM content areas than that of college-preparatory high school students. If a statistically significant difference is not found in favor of the STEM-based high school students when compared to the college-preparatory high school students, then the null hypothesis (H_0a) would be retained and a source of construct validity would not be provided.

The STEM-based high school provided 61 completed instruments to be reviewed for this instrument. The college-preparatory high school provided 83 completed instruments to be reviewed. The data collected from each instrument was analyzed for each of the identified dependent variables – *interest, ability,* and *value*. Each dependent variable was further delineated by the four content areas of STEM. The STEM content areas were reviewed individually and as a collective for each of the dependent variables. The estimated marginal means provided school mean scores for each of the dependent variables as well as for each of the STEM content areas.

Interest Mean Scores

For the dependent variable of *interest* there was a higher mean score from the college-preparatory high school students (M = 100.52, SD = 20.67) when compared to the mean score from the STEM-based high school students (M = 100.08, SD = 19.77) for all STEM content areas. The difference between the mean scores was very close and therefore did not suggest a significant difference between the two schools across the combination of STEM content areas. The highest obtainable score for this dependent variable was 144 – 9 items for all content areas with the highest possible score of 4 for each item. Provided this information, the student mean scores for each of these schools demonstrated a level of *interest* at approximately 70% (moderately positive) for all STEM content areas for both schools.

Review of each of the STEM content areas demonstrated the students in the STEM-based high school produced higher mean scores for the majority of content areas – science, technology, and engineering. The mean score differences for each of the three content areas were relatively small. The standard deviations were also too high to allow such small mean score differences to be regarded as significant based purely on observation (refer to Table 34 and Figure 7). Of these three content areas, the largest difference between the two schools that favored the STEM-based high school was for the content area of engineering. The STEM-based high school produced a mean score of 23.57(*SD* = 8.21) and the college-preparatory high school produced a mean score of 21.78 (*SD* = 8.67) for the content area of engineering, displaying a difference of only 1.79 mean score points. Based on the observation of the mean scores, the differences across the science, technology, and engineering content areas were not expected to be statistically significant.

School	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
STEM-based high school	28.57	7.98	25.82	7.11	23.57	8.21	22.15	9.19
College-preparatory high school	27.46	8.11	24.23	7.37	21.78	8.67	27.05	7.66

Note: Mean scores and standard deviations are based on a 36 point scale specific to the interest dependent variable.

Table 34. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Interest

The college-preparatory high school students demonstrated noticeably higher mean scores for the mathematics content area for the dependent variable of *interest*. The mean scores were significant enough to allow the college-preparatory high school to retain a higher mean score for the overall dependent variable of *interest*. The STEM-based high school students produced a mean score of 22.15 (SD = 9.19) for the mathematics content area while the college-preparatory high school produced a mean score of 27.05 (SD = 7.66). This was the widest margin of mean score difference displayed for the school mean score comparison. It was expected that this mean score difference would be identified as a statistical difference between the two schools.

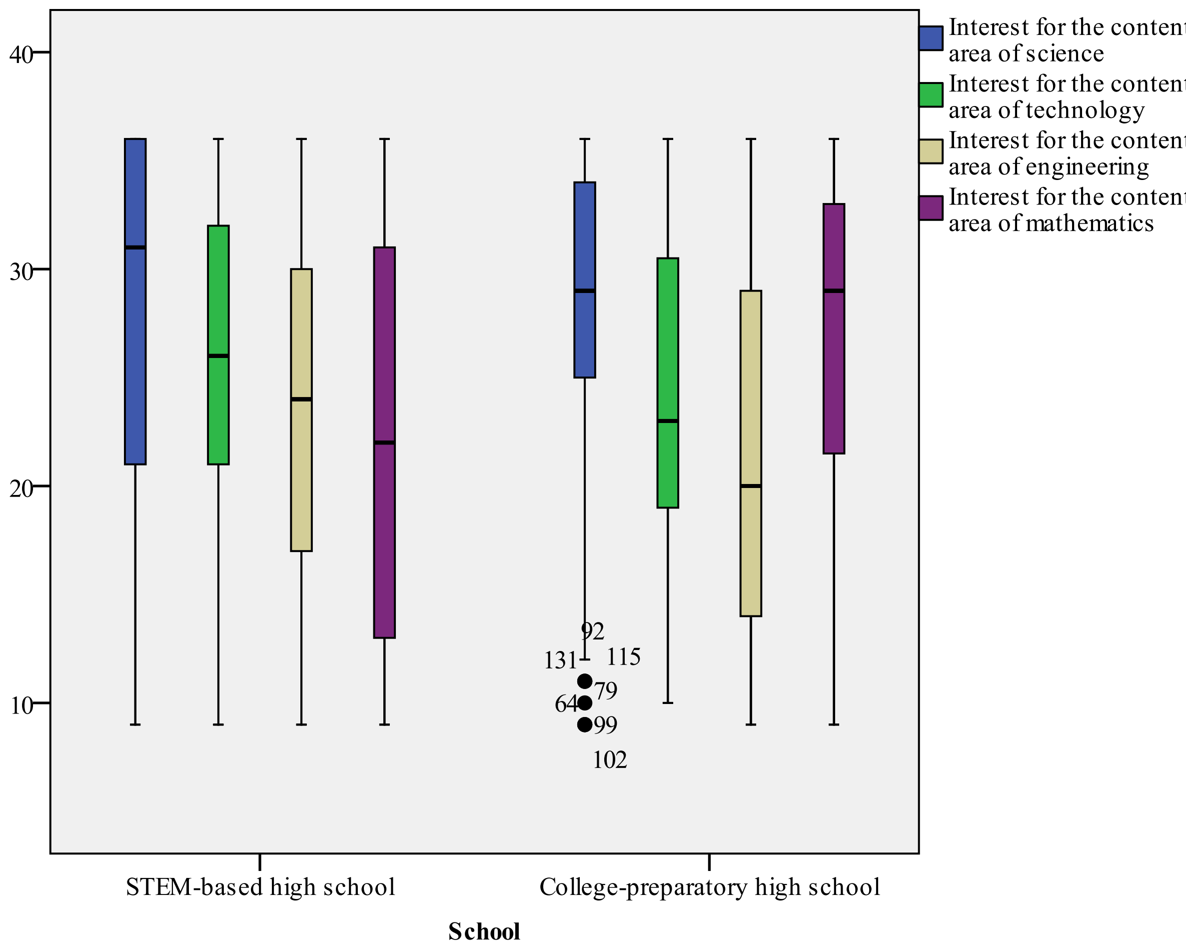


Figure 7. Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Interest

Looking purely at the mean scores, the students' *interest* toward the collective and individual content areas was determined to be moderately positive. As previously stated, the total STEM content area level of *interest* for each school was approximately 70% of the overall scale with a slight advantage demonstrated by the college-preparatory high school students' mean score. For the individual content areas, the highest obtainable score for the *interest* dependent variable was 36. Figure 8 shows the percentages for each content area and school as they were indicated by the mean scores demonstrated in Table 34.

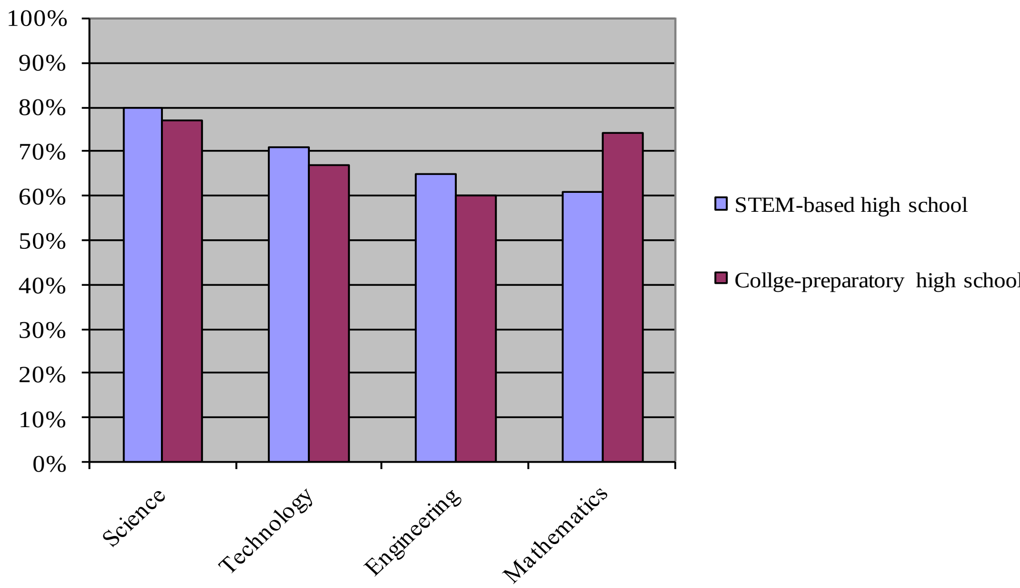


Figure 8: Percentage of Interest for Each School for Each of the STEM Content Areas as Determined by Mean Scores

The percentages for *interest* ranged between a high of 80% to a low of 60% for the two schools. For the science, technology, and engineering content areas, students from the STEM-based high school when compared to a college-preparatory high school displayed more positive percentages of *interest*; although much closer than anticipated. However, the percentage for interest for the content area of mathematics for each of the schools was surprising. It was because of the large and unexpected percentage in favor of the college-preparatory high school students for the content area of mathematics that students in the two high schools demonstrated an almost equal overall *interest* mean scores toward STEM.

Ability Mean Scores

The college-preparatory high school students demonstrated a higher mean score for the dependent variable of *ability* (M= 68.23, SD = 13.09) when compared to the mean score from the STEM-based high school students (M = 65.85, SD = 12.30) for all STEM content areas. The difference between the mean scores was close and did not appear to indicate a significant difference between the students in the two schools. The highest obtainable score for this dependent variable was 96 – 6 items for all content areas with the highest possible score of 4 for each item. Based on this information, schools' students mean scores demonstrated a level of *ability* at approximately 71% for the college-preparatory high school and approximately 69% for the STEM-based high school for all content areas. Both are considered to be moderately positive toward the dependent variable of *ability*.

Review of each of the STEM content areas demonstrated that the college-preparatory high school students produced higher mean scores for two of the content areas – engineering and mathematics. The STEM-based high school students produced higher mean scores for the remaining two content areas – science and technology. The mean score differences for two of the content areas were relatively close, less than 1 mean score point difference for the science and engineering content areas (see Table 35). The largest mean score difference between students in the two schools, in favor of the college-preparatory high school, was for the content area of mathematics.

School	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
STEM-based high school	18.48	4.69	17.16	4.93	14.30	5.65	15.92	6.24
College-preparatory high school	18.43	5.22	15.54	4.93	14.69	5.28	19.57	5.16

Note: Mean scores and standard deviations are based on a 24 point scale specific to the ability dependent variable.

Table 35. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Ability

Students in the college-preparatory high school produced a mean score of 19.57 (*SD* = 5.16) and the STEM-based high school produced a mean score of 15.92 (*SD* = 6.24) for the content area of mathematics, a difference of 3.65 mean score points. It was anticipated that the difference in mean scores for the dependent variable of *ability* between students in the two schools would be statistically significant for the content area of mathematics. The STEM-based high school students produced a higher mean scores for the technology content area for the dependent variable of *ability*. The STEM-based high school students produced a mean score of 17.16 (*SD* = 4.93) for the technology content area while the college-preparatory high school produced a mean score of 15.54 (*SD* = 4.93). It was anticipated that the mean score difference for the dependent variable of *ability* would indicate a statistically significant difference between students in the two schools in favor of the STEM-based high school for the content area of technology.

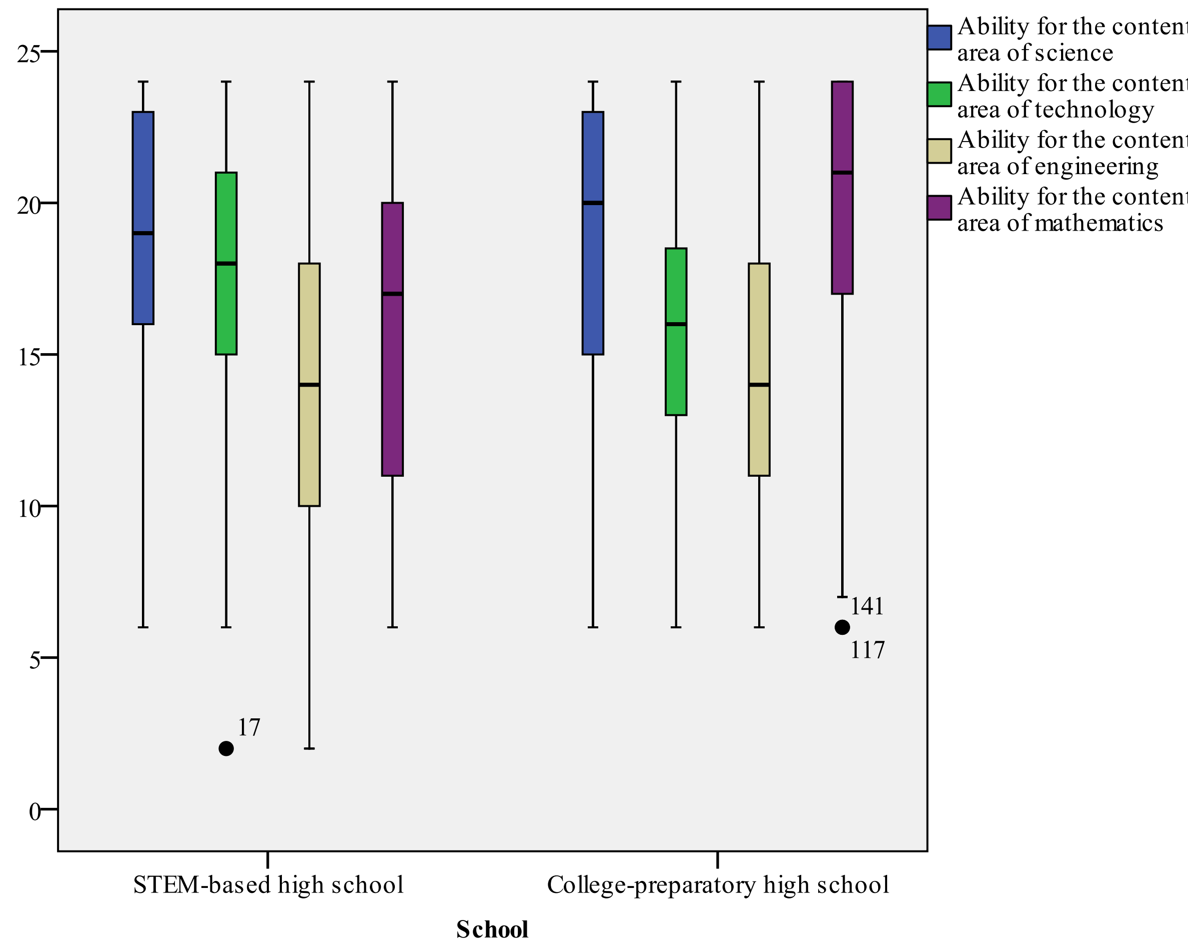


Figure 9. Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Ability

As previously stated, the total STEM content area level of *ability* for students in each school was approximately 71% for the college-preparatory high school and 69% for the STEM-based high school – moderately positive. The individual content areas for the *ability* dependent variable had a highest obtainable score of 24 – 6 items with the highest possible score of 4 for each item. Figure 10 shows the percentages for each content area and school as they were indicated by student mean scores demonstrated in Table 35.

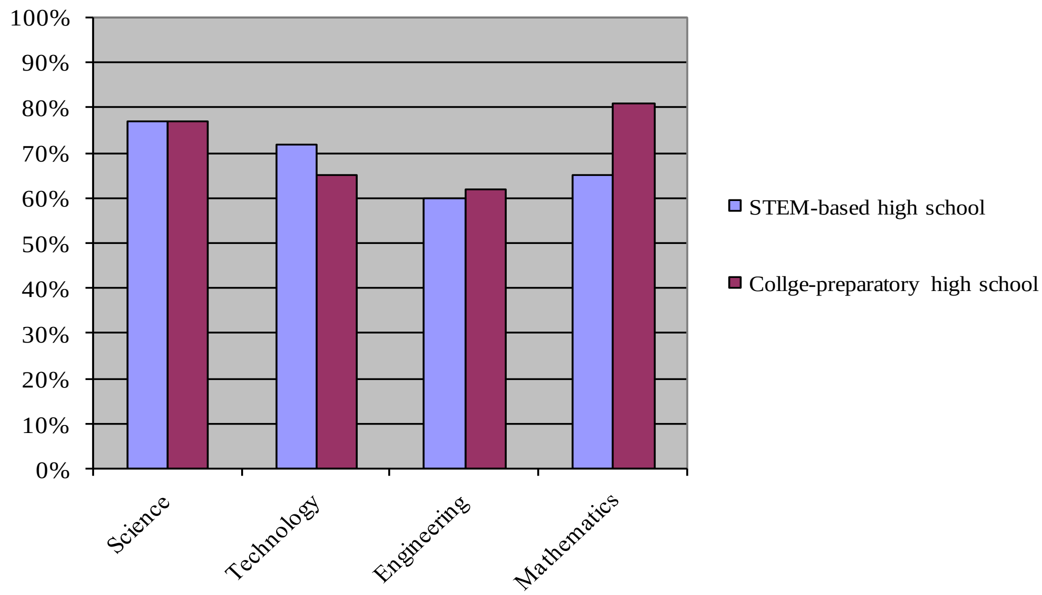


Figure 10. Percentage of Ability for Each School for Each of the STEM Content Areas as Determined by Mean Scores

The percentages for *ability* ranged between 81% and 60% for students in the two schools. For the science and engineering content areas, there was a slight difference between the mean scores for students in each of the schools, but this difference is basically negligible due to the lack of substantial difference between the mean scores and the high standard deviations. A comparison of mean scores for the technology content area aligned more with what would be expected when comparing mean scores between a STEM-based high school and the college-preparatory high school; there was a definite difference favoring students in the STEM-based program. Similar to the results for the *interest* dependent variable, *ability* for the mathematics content area for students in the two schools was surprising. Although there was a large and unexpected difference between mean scores for the content area of mathematics that favored the college-preparatory high school students, students in the two high schools demonstrated similar overall *ability* mean scores toward STEM.

Value Mean Scores

For the dependent variable of *value*, the college-preparatory high school students demonstrated a higher mean score (M = 98.02, SD = 17.40) when compared to the mean score from the STEM-based high school students (M = 97.84, SD = 19.89) for all STEM content areas. The difference between the mean scores was very close and did not appear to indicate a significant difference between students in the two schools. The highest obtainable score for this dependent variable was 128 – 8 items for all content areas with the highest possible score of 4 for each item. Based on this information, the level of *value* for all STEM content areas was approximately 77% for the college-preparatory high school students and approximately 76% for the STEM-based high school students. Both are considered to be moderately positive related to the dependent variable of *value*.

Review of each of the STEM content areas demonstrated that the college-preparatory high school students produced higher mean scores for the content areas of science and mathematics while the STEM-based high school students produced higher mean scores for the content areas of technology and engineering. The difference between the mean scores demonstrated by the students in the two schools constituted a range of less than 2 points for three of the STEM content areas – science, technology, and engineering (see Table 36). The exception to this condition was demonstrated for the mathematics content area. The college-preparatory high school students produced a mean score of 27.30 (*SD* = 5.89) and the STEM-based high school students produced a mean score of 24.26 (*SD* = 7.11) for the content area of mathematics – a difference of 3.04 mean score points. It was anticipated that the dependent variable of *value* for the mathematics content area would be statistically significant.

School	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
STEM-based high school	26.13	5.99	25.10	6.24	22.34	7.77	24.26	7.11
College-preparatory high school	26.59	6.24	23.20	6.11	20.93	7.75	27.30	5.89

Note: Mean scores and standard deviations are based on a 32 point scale specific to the value dependent variable.

Table 36. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Value

As previously stated, the total STEM content area level of *value* was approximately 77% for the college-preparatory high school students and 76% for the STEM-based high school students – moderately positive. The individual content areas for the *value* dependent variable had a highest obtainable score of 32 – 8 items with the highest possible score of 4 for each item. Figure 12 shows the percentages of each content area and school as they were indicated by the mean scores demonstrated in Table 36.

The percentages of *value* ranged between 85% and 64% for students in the two schools. The STEM-based high school students demonstrated slightly higher mean scores for the technology and engineering content areas. The college-preparatory high school students demonstrated a slight advantage for *value* for the science content area. These differences were negligible due to the close mean scores and large standard deviations. Similar to the *interest* and the *ability* dependent variables, *value* for the mathematics content areas for students in the two schools was surprising. Although there was a large and unexpected difference between mean scores for the content of mathematics that favored the college-preparatory high school students, students in the two high schools demonstrated similar overall *value* mean scores toward STEM.

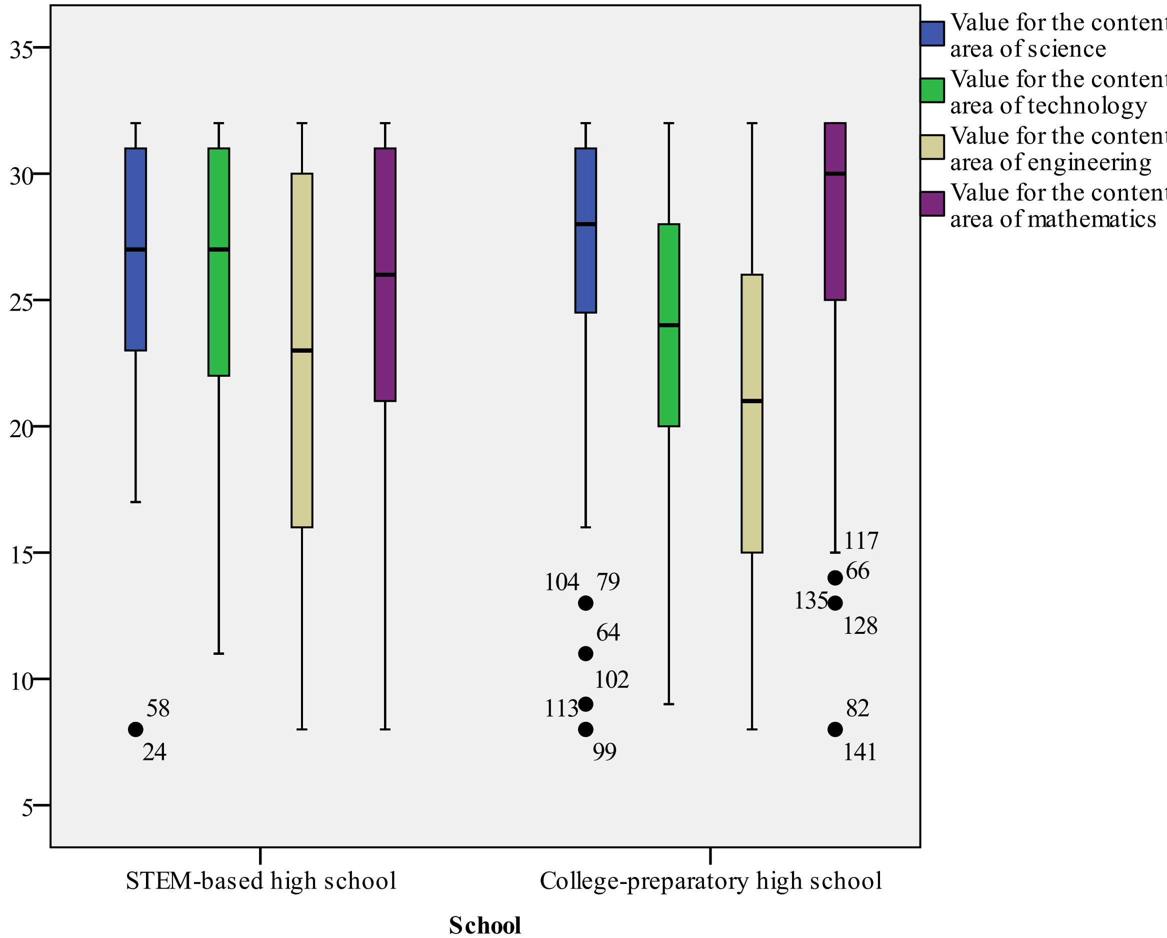


Figure 11. *Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Value*

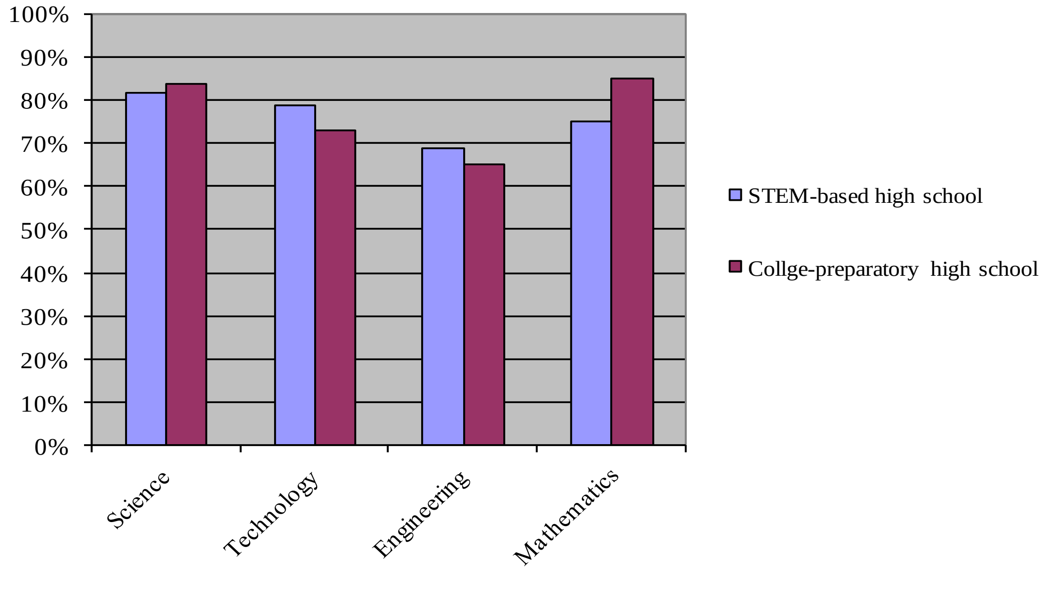


Figure 12. Percentage of Value for Each School for Each of the STEM Content Areas as Determined by Mean Scores

At this point trends were observed for the four content areas of STEM and student overall attitudes toward STEM. Students in both schools displayed similar levels of attitude for the content areas of science, technology, and engineering. Between the three content areas, student mean scores (between 76% and 83%) were consistently the highest for the content area of science. This was true for students in both schools. The same can be concluded for the content area of technology, except at a slightly lower percentage (between 65% and 79%). The content area of engineering had the overall lowest percentage of positive attitude for students in both schools (between 60% and 69%). The major area of difference between students in the two schools was observed for the content area of mathematics. Students in the college-preparatory high school demonstrated a more positive attitude toward the mathematics content area (between 75% and 85 %) when compared to students in the STEM-based high school (between 62% and 75%). This incredible difference in overall attitude toward mathematics was unexpected between students in the two schools.

Testing for Assumptions

Two assumptions were reviewed during the preceding analyses – normality and homogeneity of variance. Independence was considered when the instrument packets were first administered to the students at each school. The students were instructed by the researcher to complete the attitudinal packets at home and by themselves. It was adamantly reinforced that the researcher was interested in each student's personal responses and that the instrument would provide them an opportunity to voice their honest opinion regarding the content areas of STEM. Additionally, the researcher instructed the students that any instrument not correctly filled out as specified by the directions would not be used during the analyses and would remove the student from entry into each school's incentive/raffle contest. It was therefore assumed that the students completed each packet independently as they were directed by the researcher. Review of the instruments while collecting the data also provided no clear indication of collaborative work by the students from either school.

Homogeneity of variance (homoscedasticity) refers to the assumption that the variances between the two schools are equal. Violation of homogeneity can lead to an increase of Type I or Type II error rate. Additional concerns regarding unequal and small *n*'s increase the likelihood of violating the assumption of homogeneity. To determine an equal variance between the two schools, Levene's test procedure was utilized (see Table 37). Based on this analysis, only the dependent variable of *interest* for the content area of mathematics indicated a significant relationship ($p < .05$) and therefore a possible violation of homogeneity of variance.

Review of the other levels of dependent variables indicated that the content area of mathematics did not show a strong variance between groups among any of the three dependent variables when compared to other content areas (*ability*, $p = .163$; *value*, $p = .083$).

Dependent variable	Levene statistic	*df1*	*df2*	Sig.
Interest for all STEM content areas	.000	1	142	.985
Interest for the content area of science	.431	1	142	.512
Interest for the content area of technology	.659	1	142	.418
Interest for the content area of engineering	.725	1	142	.396
Interest for the content area of mathematics	4.590	1	142	.034*
Ability for all STEM content areas	.847	1	142	.359
Ability for the content area of science	1.340	1	142	.249
Ability for the content area of technology	.009	1	142	.923
Ability for the content area of engineering	.779	1	142	.379
Ability for the content area of mathematics	1.963	1	142	.163
Value for all STEM content areas	2.750	1	142	.099
Value for the content area of science	.045	1	142	.832
Value for the content area of technology	.033	1	142	.856
Value for the content area of engineering	.008	1	142	.930
Value for the content area of mathematics	3.039	1	142	.083

* Indicates significance and possible violation of homogeneity, $p < .05$

Table 37. Tests for Homogeneity of Variance for the Independent Variable of School

This lack of equal variance between the two schools for the content area of mathematics made determinations regarding the content area of mathematics seemingly risky and thereby increased the opportunity for a Type I error rate. However, the same items and subjects were used for the other three content areas which did not display any concerns regarding homogeneity. Further review of this condition will be considered in chapter 5. Another assumption that still needed to be addressed is that of normality. Levene's test is not robust to conditions of non-normality.

The assumption of a normal distribution was verified by review of the frequency distributions and statistical procedures. Review of the frequency distributions indicated negatively skewed distributions for the majority of the dependent variables. Additionally, some of the distributions have indicated a strong platykurtic distribution caused by the large standard deviations. This was especially the case for the science and mathematics content areas. Violations of normality are typically minimal when evaluating sample data. Observations of the distributions did not raise immediate concerns regarding violations of normality. To be certain, further statistical procedures were also performed. This was done because of the unequal and low number of students in the sample from each school.

To assure normal distribution, the Kolmogorov-Smirnov and the Shapiro-Wilk tests were administered to data for the independent variable of school (see Table 38). Upon review of the tests, it was determined that the majority of distributions were not normally distributed ($p < .05$). Both tests were reviewed to draw this conclusion. The only exception to this condition was found for the dependent variable of *ability* for the content area of engineering.

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Dependent variable	School	Statistic	df	Sig.	Statistic	df	Sig.
Interest for all STEM content areas	College-prep. high school	.151	83	.000	.936	83	.000
	STEM-based high school	.187	61	.000	.950	61	.014
Interest for the content area of science	College-prep. high school	.146	83	.000	.865	83	.000
	STEM-based high school	.216	61	.000	.844	61	.000
Interest for the content area of technology	College-prep. high school	.076	83	.200*	.957	83	.008
	STEM-based high school	.093	61	.200*	.956	61	.027
Interest for the content area of engineering	College-prep. high school	.120	83	.005	.925	83	.000
	STEM-based high school	.115	61	.044	.945	61	.008
Interest for the content area of mathematics	College-prep. high school	.143	83	.000	.903	83	.000
	STEM-based high school	.105	61	.093	.922	61	.001
Ability for all STEM content areas	College-prep. high school	.181	83	.000	.901	83	.000
	STEM-based high school	.191	61	.000	.922	61	.001
Ability for the content area of science	College-prep. high school	.146	83	.000	.887	83	.000
	STEM-based high school	.135	61	.008	.913	61	.000
Ability for the content area of technology	College-prep. high school	.070	83	.200*	.968	83	.037
	STEM-based high school	.084	61	.200*	.950	61	.014
Ability for the content area of engineering	College-prep. high school	.107	83	.019	.954	83	.005
	STEM-based high school	.117	61	.038	.963	61	.062
Ability for the content area of mathematics	College-prep. high school	.195	83	.000	.819	83	.000
	STEM-based high school	.117	61	.036	.936	61	.003
Value for all STEM content areas	College-prep. high school	.139	83	.000	.924	83	.000
	STEM-based high school	.167	61	.000	.893	61	.000
Value for the content area of science	College-prep. high school	.204	83	.000	.810	83	.000
	STEM-based high school	.176	61	.000	.867	61	.000

(Continued)

Table 38. Tests for Normality for the Independent Variable of School

Table 38. (Continued)

Value for the content area of technology	College-prep. high school	.075	83	.200*	.955	83	.006
	STEM-based high school	.135	61	.008	.898	61	.000
Value for the content area of engineering	College-prep. high school	.108	83	.018	.934	83	.000
	STEM-based high school	.117	61	.038	.919	61	.001
Value for the content area of mathematics	College-prep. high school	.228	83	.000	.782	83	.000
	STEM-based high school	.141	61	.004	.893	61	.000

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

The normal distribution for the content area of engineering was only established for the STEM-based high school students and not for the college-preparatory high school students. Lilliefors significance correction was also provided by the Kolmogorov-Smirnov test. This correction allowed for the content area of technology not to appear significant for the violation of normality (see Table 38). However, the Lilliefors significance correction removed pertinent outliers from the data and thereby focused the distribution so that it may appear normal.

Removal of data, given the small *n*, would greatly influence the remainder of the instrument review. The purpose of this study was to create an instrument that may identify student attitudes toward STEM, not necessarily extrapolate the findings of the instrument to a larger population, at least as of yet. Future studies with larger sample sizes will more carefully address the concern regarding the assumption of normality. For the purposes of this study, the data will remain intact and outliers will still be reviewed. The Shapiro-Wilk test confirmed that when provided the full data set for analyses, the distribution is not normal. The lack of normality decreases the robustness of the Levene's test for homogeneity of variance and may have increased the opportunity for Type I errors for all dependent variables and associated content areas.

The violation of the normality assumption suggested certain concerns regarding the samples. One possible concern is that of sample bias. The samples obtained for this study could exhibit favoritism toward STEM content areas and thereby create negatively skewed distributions. Realistically, the population may not provide a normal distribution with regard to student attitudes toward STEM. Since this is unknown, transformations of the data would be unsubstantiated.

Finally, the test items themselves could have a positive bias and therefore would not correctly represent an accurate and balanced range of attitudinal items. The violation of these assumptions, in addition to unequal and small *n*'s, required the use of non-parametric analysis procedures. Both parametric and non-parametric analyses were applied to the school comparison data. It was anticipated that using both analyses would aid in clearly identifying any demonstrated significant differences between students in the two schools.

Analysis of Variance

Due to the collection of dependent variables, a general linear model (GLM) multivariate test was applied to the data as part of the SPSS MANOVA procedure. The independent variable of school was identified as significant by the multivariate tests (see Table 39). The identified significance only suggests that students in the STEM-based high school and college-preparatory high school do differ statistically for one or more of the reviewed dependent variables.

Effect		Value	*F*	Hyp. *df*	Error *df*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed power
School	Pillai's Trace	.25	3.47	12	125	.000***	.250	41.65	.996
	Wilks' Lambda	.75	3.47	12	125	.000***	.250	41.65	.996
	Hotelling's Trace	.33	3.47	12	125	.000***	.250	41.65	.996
	Roy's Larget Root	.33	3.47	12	125	.000***	.250	41.65	.996

*** $p < .001$.

Table 39. Multivariate Test for the Independent Variable of School

The univariate analysis of the student samples was provided by the MANOVA procedure. This analysis demonstrated the dependent variables and content areas that provided a statistically significant difference between the students in the two schools. The content area of mathematics provided statistical significance for the independent variable of school for all dependent variables; *interest* (F = 12.67, p = .001), *ability* (F = 16.61, p = .000), and *value* (F = 9.55, p = .003). Also, the observed power was very strong and the effect size represented an overall medium effect as indicated by the univariate analysis (see Table 40). The content area of technology did not provided statistical significance for the independent variable of school. However, review of the data demonstrates that the dependent variables of *ability* (F = 3.15, p = .078) and *value* (F = 3.63, p = .059) for the content area of technology were close to demonstrating statistically significant results. This will be reviewed in future analyses with larger sample and more varied sizes. As previously suggested, the college-preparatory school exhibited higher mean scores across each of the dependent variables for the mathematics content area when compared to the STEM-based high school mean scores (refer back to Tables 34, 35, and 36).

Content area	Dependent variable	Mean Squared	*df*	*F*	Sig.	Partial Eta Squared	Observed power
Science	Interest	28.72	1	.46	.500	.003	.103
	Ability	.55	1	.023	.879	.085	.942
	Value	13.68	1	.36	.548	.003	.092
Technology	Interest	76.47	1	1.48	.226	.011	.227
	Ability	73.38	1	3.15	.078	.023	.422
	Value	129.80	1	3.63	.059	.026	.472
Engineering	Interest	76.07	1	1.28	.260	.009	.203
	Ability	8.72	1	.337	.568	.002	.089
	Value	64.29	1	1.27	.261	.009	.202
Mathematics	Interest	819.29	1	12.63	.001**	.085	.942
	Ability	465.48	1	16.11	.000***	.106	.979
	Value	348.48	1	8.96	.003**	.062	.844

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 40. Univariate Tests for the Independent Variable of School b content area by interest, ability, and value

To assure these analyses are accurate, a non-parametric analysis was also conducted to determine the significant differences between students in the two schools. The Kruskal-Wallis test was utilized due to the violations of normality and homogeneity (specifically regarding mathematics content area) as previously discussed. The Kruskal-Wallis test results matched the results of the univariate analysis for the independent variable of school regarding the content area of mathematics (see Table 41). All dependent variables along the content area of mathematics were demonstrated as statistically significant ($p < .01$). The statistical significance from both of the parametric and non-parametric analyses aligns with the observations made during the mean comparisons produced prior to the data analysis.

Careful attention must still be taken regarding implications of the statistical significance due to the violations of normality and homogeneity of variance from the utilized samples. Also identified as significant were differences for the content area of technology for the dependent variables of *ability* and *value*. The significance of technology content area along the two dependent variables was not indicated during the univariate analysis nor was it indicated during the mean comparison produced at the beginning of the data analysis.

Content area	Dependent variable	Chi-squared	df	Asymp. Sig
Science	Interest	1.72	1	.190
	Ability	.04	1	.836
	Value	.290	1	.590
Technology	Interest	2.18	1	.140
	Ability	4.26	1	.039*
	Value	4.17	1	.041*
Engineering	Interest	1.71	1	.190
	Ability	.22	1	.643
	Value	1.12	1	.293
Mathematics	Interest	10.11	1	.001**
	Ability	15.77	1	.000***
	Value	7.45	1	.006**

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 41. Kruskal-Wallis Test for the Independent Variable of School by content area by Interest, Ability, and Value

Provided the lack of supporting evidence from other analyses and the associated violations of normality regarding technology content area, this statistical significance produced by the Kruskal-Wallis test is not considered vital to the purpose of this study.

Summary of the Analysis – School

It was hypothesized that a statistically significant difference would be ascertained between the STEM-based high school students and the college-preparatory high school students. This hypothesized difference would indicate that students at the STEM-based high school would exhibit more positive attitudes for STEM when compared to students at the college-preparatory high school. This hypothesis was not supported by the analysis of the data. In fact, the only statistical significance found suggested that the college-preparatory high school students exhibited more positive attitudes toward the content area of mathematics when compared to the STEM-based high school students.

Grade Level

It was hypothesized that students exposed to STEM education for a longer period of time (i.e., higher grade level) will exhibit a more positive attitude toward STEM than students enrolled for a shorter duration (i.e., lower grade level) (Hypothesis B, H_1b). The reasoning for this hypothesis was due to the extended length of time and curricular experience that students in the eleventh-grade would have when compared to students in the ninth-grade. The CBAM and the associated research material suggested that change in subjects occurs over time and experience. The individual modes of the suggested change described by the CBAM will be considered for future research; however, the overall attitudinal development toward STEM should be measurable between the two grade levels. This hypothesis was considered especially for the STEM-based high school, a program that intended to produce STEM associated skills and interest. The two high schools collectively provided completed instruments from 83 ninth-grade students and 61 eleventh-grade students. The data from the independent variable of grade level was exposed to the same analyses that were used for the data from the independent variable of school.

Interest Mean Scores

For the dependent variable of *interest* there was a higher mean score from the ninth-grade students (M = 103.70, SD = 20.85) when compared to the mean score from the eleventh-grade students (M = 95.75, SD = 18.55) for all of the STEM content areas. The difference between the mean scores may indicate a significant difference between the students in the two grade levels. The highest obtainable score for this dependent variable was 144 – 9 items for all content areas with the highest possible score of 4 for each item. Given this range, the students mean scores for the grade levels demonstrated a level of *interest* at approximately 72% for the ninth-grade students and 67% for the eleventh-grade students for all STEM content areas.

Review of each of the STEM content areas demonstrated the ninth-grade students produced higher mean scores for the content areas of engineering and mathematics. The eleventh-grade students provided higher mean scores for the content areas of science and technology. The majority of difference between the students mean scores demonstrated by the two grade levels constituted a range less than 2 mean score points and was not expected to be statistically significant based on observation (see Table 42).

The exception to this condition was demonstrated for the mathematics content area. The ninth-grade students produced a mean score of 27.08 (SD = 8.40) and the eleventh-grade students produced a mean score of 22.07 (SD = 8.22) for the content area of mathematics – a difference of 5.01 mean score points. It was anticipated that the difference between the students mean scores for the mathematics content area would be statistically significant. The difference between mean scores for the content area of mathematics was the largest margin for the overall independent variable of grade level.

As previously stated, the percentage of *interest* for all content areas was 72% for the ninth-grade students and 67% for the eleventh-grade students – both considered to be moderately positive. The individual content areas for the *interest* dependent variable had a highest obtainable score of 36 – 9 items with the highest possible score of 4 for each item. Figure 14 shows the percentages of each content area and grade level as they were indicated by the mean scores demonstrated in Table 42.

Grade level	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Ninth-grade	27.77	8.11	25.06	7.71	23.78	8.22	27.08	8.40
Eleventh-grade	28.15	8.02	24.69	6.70	20.85	8.63	22.07	8.22

Note: Mean scores and standard deviations are based on a 36 point scale specific to the interest dependent variable.

Table 42. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Interest

The percentages of *interest* ranged between 80 and 60% for the students in the two grade levels. Students in the two grade levels provided mean scores for the science, technology, and engineering content areas displayed regarding *interest* that were almost equivalent. Some variation may be witnessed for the content area of engineering; the ninth-grade students demonstrated a stronger indication of *interest* toward the content area of engineering. However, standard deviations between the mean scores would suggest that this close of a margin may be negligible. However, the percentage for interest for the content area of mathematics for each of the grade levels was surprising. Reviewing this data could permit some to infer that students begin to lose *interest* in mathematics as they progress through advanced grade levels. At the same instance, the students appear to have retained comparable levels of *interest* along the other three content areas of STEM. Further investigation into this result will be required.

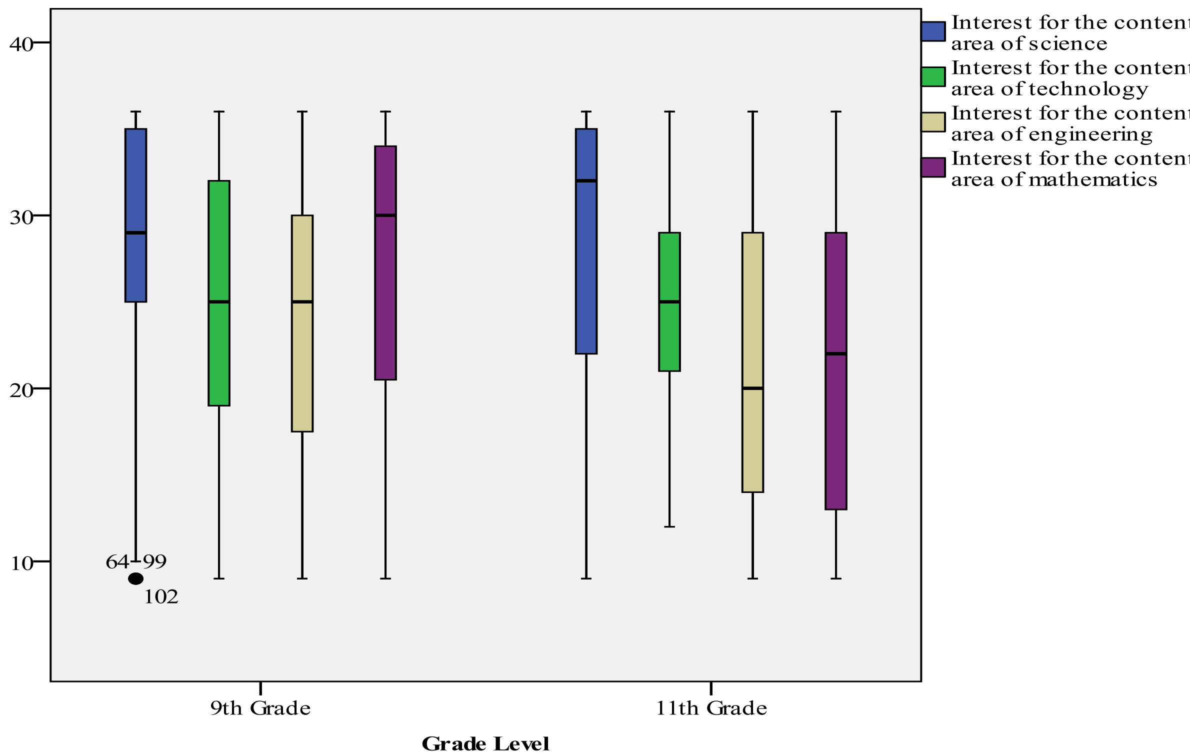


Figure 13. Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Interest

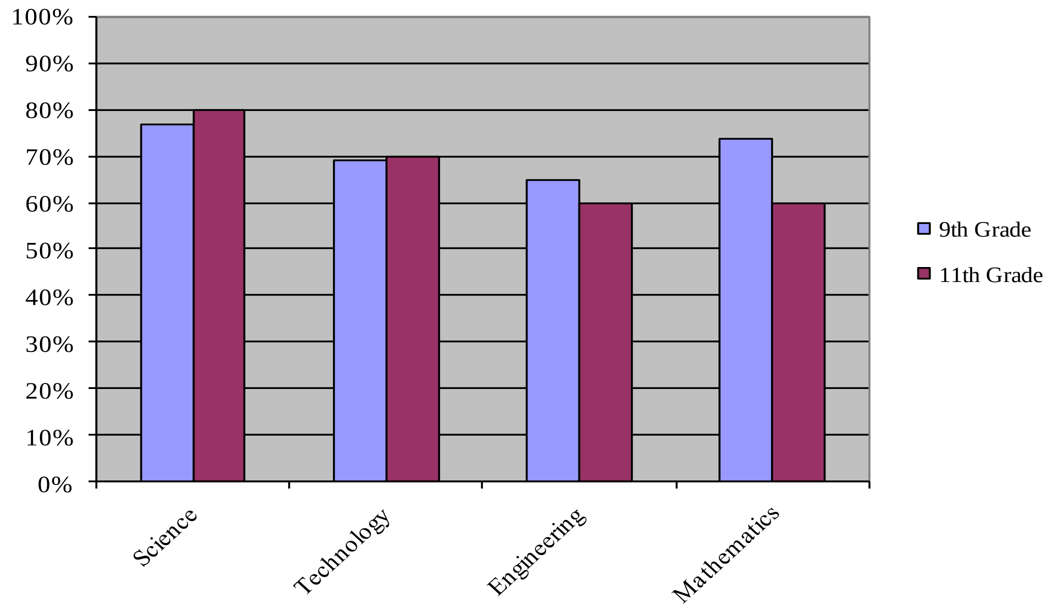


Figure 14. Percentage of Interest for Each Grade Level for Each of the STEM Content Areas as Determined by Mean Scores

Ability Mean Scores

Ninth-grade students (*M* = 68.40, *SD* = 13.93) demonstrated a higher mean score for the dependent variable of *ability* when compared to the mean score from the eleventh-grade students (*M* = 65.62, *SD* = 10.92) for all STEM content areas. The difference between the student mean scores was very small and did not appear to indicate a possible significant difference between students in the two grade levels. The highest obtainable score for this dependent variable was 96 - 6 items for all content areas with the highest possible score of 4 for each item. Given this range, the students mean scores demonstrated a level of *ability* at approximately 71% for the ninth-grade level and 68%

for the eleventh-grade level for all content areas. Both are considered to be moderately positive toward the dependent variable of *ability*.

Grade level	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Ninth-grade	18.57	4.92	16.06	5.32	14.82	5.51	18.95	5.40
Eleventh-grade	18.30	5.17	16.46	4.50	14.15	5.31	16.75	5.85

Note: Mean scores and standard deviations are based on a 24 point scale specific to the ability dependent variable.

Table 43. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Ability

Review of each of the STEM content areas demonstrated the eleventh-grade students produced higher mean scores for the majority of content areas – science, technology, and engineering. The mean score differences for the three content areas was very close, less than 1 mean score point difference between grade level mean scores. The content area of mathematics demonstrated the largest mean score difference for the students in the two grade levels. This was the only content area for the dependent variable of *ability* that revealed more positive results for the ninth-grade students. The ninth-grade students produced a mean score of 18.95 (*SD* = 5.40) and the eleventh-grade students produced a mean score of 16.75 (*SD* = 5.85) for the content area of mathematics, a difference of only 2.20 mean score points. Although this mean score difference between the students in the two grade levels was small in number, it was twice the difference between mean scores than any other content area for the *ability* dependent variable. It was anticipated that the *ability* dependent variable for the mathematics content area may show some statistical significance.

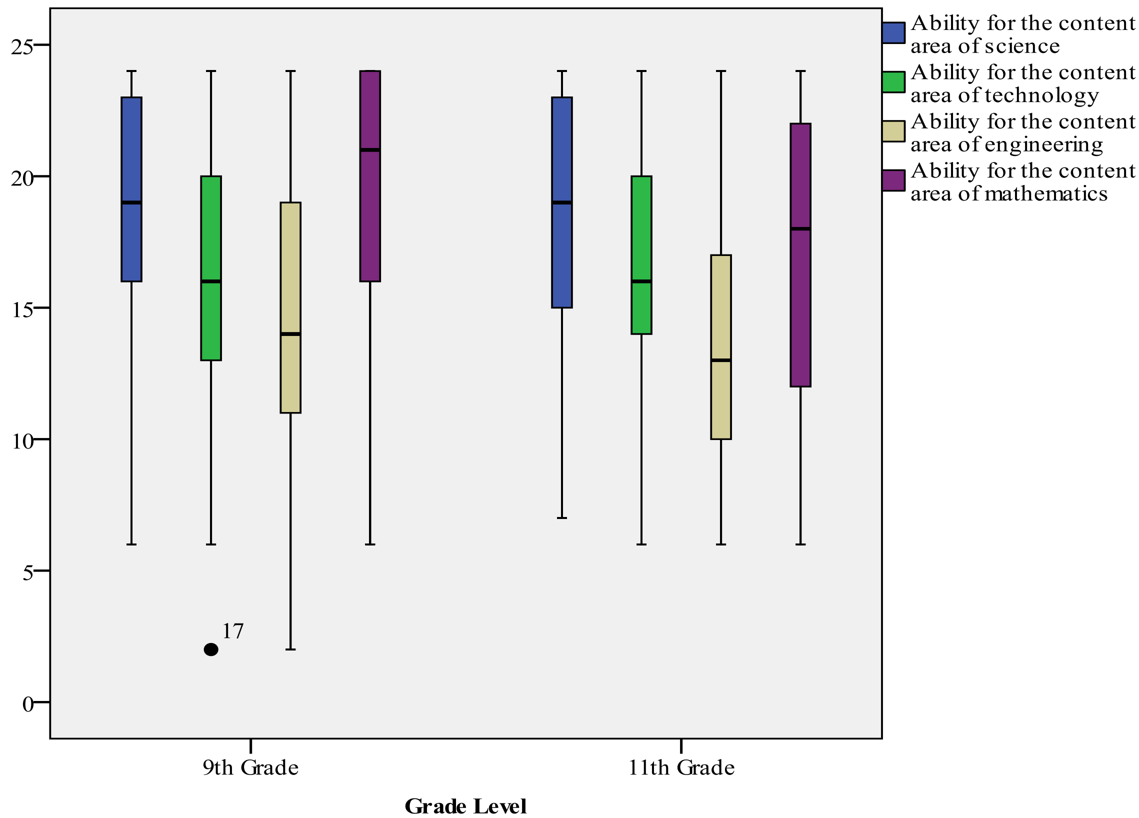


Figure 15. Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Ability

As previously stated, the total STEM content area level of *ability* was approximately 71% for the ninth-grade students and 68% for the eleventh-grade students – moderately positive for both grade levels. The individual content areas for the *ability* dependent variable had a highest obtainable score of 24 - 6 items with the highest possible score of 4 for each item. Figure 16 shows the percentages of each content area and grade levels as they were indicated by the student mean scores demonstrated in Table 43.

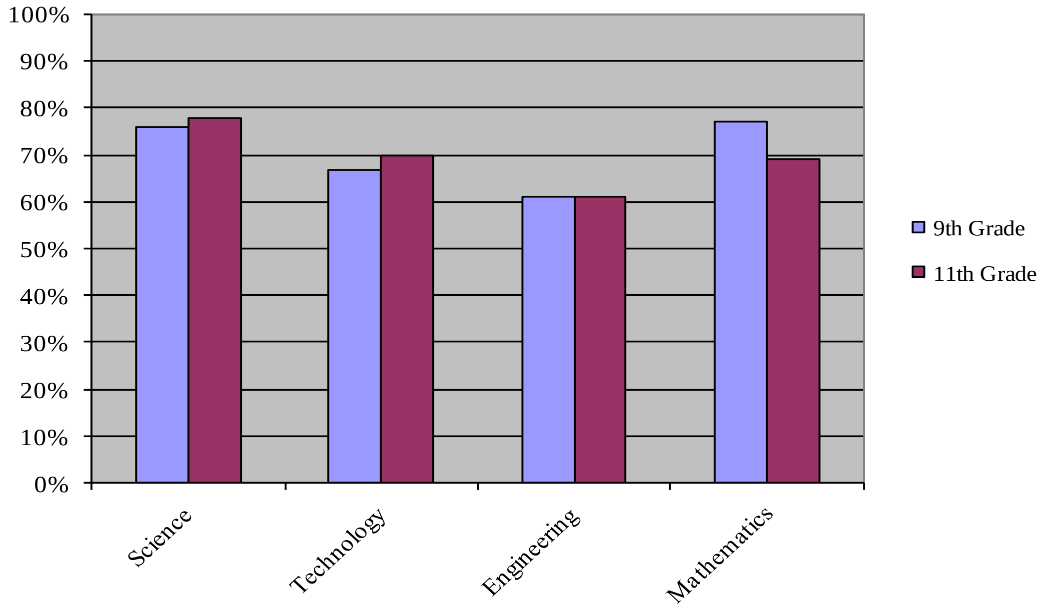


Figure 16. Percentage of Ability for Each Grade Level for Each of the STEM Content Areas as Determined by Mean Scores

The percentages of *ability* ranged between 78% and 61% for the students in the two grade levels. Similar to what was indicated by the review of the dependent variable of *interest*, the content area of mathematics again revealed the only observed significant difference between students in the two grade levels. The ninth-grade students demonstrated higher mean scores for the mathematics content area. The eleventh-grade students demonstrated higher mean scores for science, technology, and engineering content area, but are basically negligible due to their lack of substantial difference.

Further investigation into this result will be required regarding the difference of *ability* between ninth and eleventh-grade students for the content area of mathematics.

Value Mean Scores

Ninth-grade students (*M* = 100.66, *SD* = 18.94) demonstrated a higher mean score on the dependent variable of *value* when compared to the mean score from the eleventh-grade students (*M* = 94.25, *SD* = 17.18) for all STEM content areas. The difference appeared to indicate a possible significant difference between students in the two grade levels. The highest obtainable score for this dependent variable was 128 – 8 items for all content areas with the highest possible score of 4 for each item. Given this range, the students mean scores demonstrated a level of *value* at approximately 79% for the ninth-grade students and approximately 74% for the eleventh-grade students for all STEM content areas. Both are considered to be moderately positive toward the dependent variable of *value*.

Grade level	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Ninth-grade	26.27	6.26	24.13	6.41	22.77	7.54	27.49	5.72
Eleventh-grade	26.57	5.97	23.84	5.99	19.84	7.79	24.00	7.17

Note: Mean scores and standard deviations are based on a 32 point scale specific to the value dependent variable.

Table 44. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Value

Review of each of the STEM content areas demonstrated the ninth-grade students produced higher mean scores for the content areas of engineering and mathematics. The eleventh-grade students produced higher mean scores for the content areas of science and technology. The majority of difference between the mean scores demonstrated by students in the two grade levels constituted a range less than 2 points and therefore was not expected to be statistically significant for the *value* dependent variable (see Table 44).

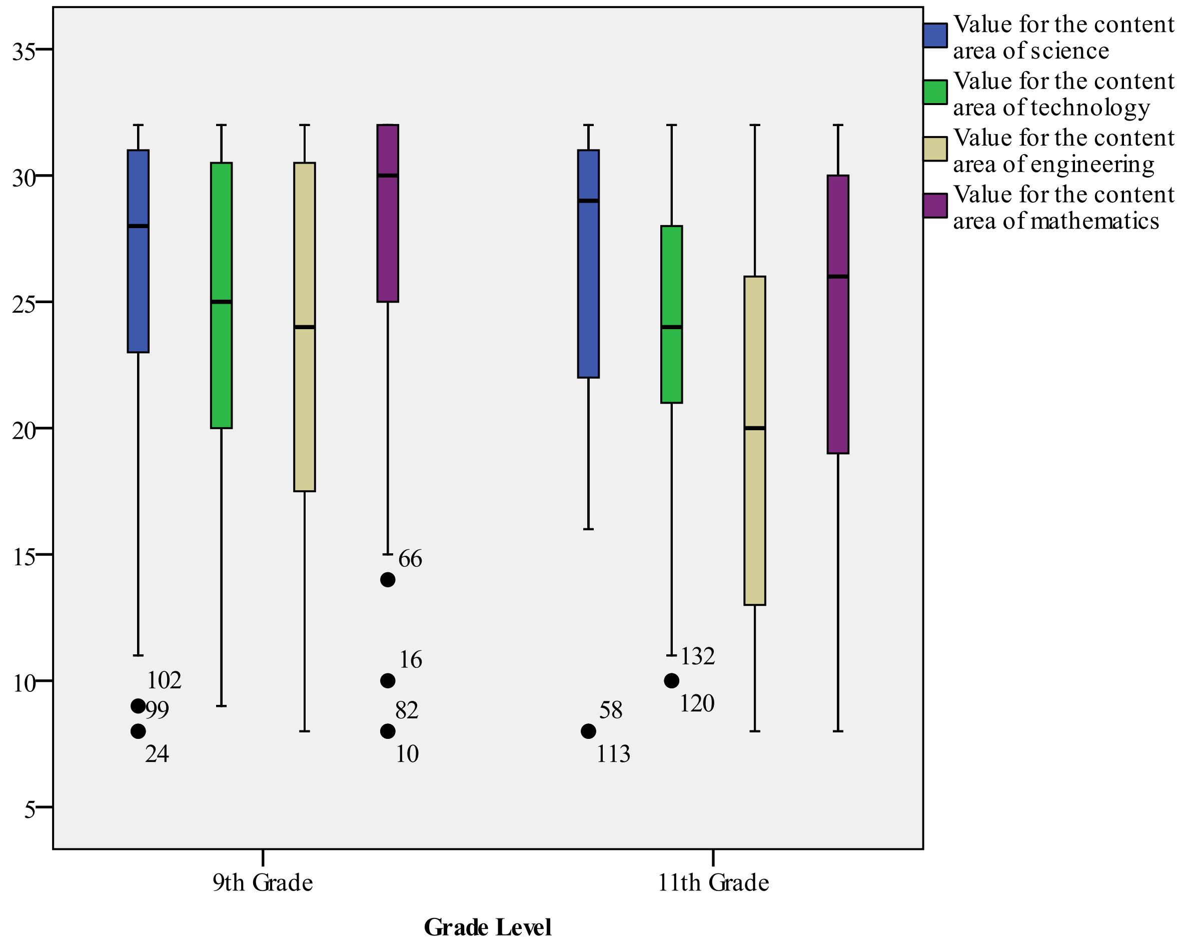


Figure 17. *Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Value*

The exception to this condition was demonstrated for the mathematics content area. The ninth-grade students produced a mean score of 27.49 (*SD* = 5.72) and the eleventh-grade students produced a mean score of 24.00 (*SD* = 7.17) for the content area of mathematics, a difference of 3.49 mean score points. It was anticipated that the mean score for the dependent variable of *value* would be statistically significant for the content area of mathematics.

As previously stated, the total STEM content area of *value* was approximately 79% for the ninth-grade students and 74% for the eleventh-grade students – both considered to be moderately positive. The individual content areas for the *value* dependent variable had a highest obtainable score of 32 – 8 items with a highest possible score of 4 for each item. Figure 18 shows the percentages of each content area and grade level as they were indicated by the student mean scores demonstrated in Table 44.

The percentages of *value* ranged between 85% and 64% for students in the two grade levels. Similar to what was indicated by the review of the dependent variables of *interest* and *ability*, the content area of mathematics demonstrated the only observed significant different between students in the two grade levels. The eleventh-grade students demonstrated higher mean scores for the science and technology content areas, but are basically negligible due to their lack of substantial difference. Some variation may be witnessed for the content area of engineering; the ninth-grade students exhibited a stronger percentage of *value* toward the content area. This condition was also observed within the dependent variable of *interest*. However, standard deviations between the student mean scores would suggest that this small of a margin may be negligible and not statistically significant.

At this point trends were observed for the four content areas of STEM and student overall attitudes toward STEM. Students in both grade levels displayed a similar attitude for the content areas of science, technology, and engineering. Between the three content areas, student mean scores (between 76% and 84%) were consistently the highest for the content area of science. The same can be said for technology content area, except at a slightly lower percentage of positive attitude (between 65% and 80%). The content area of engineering had the overall lowest percentage of positive attitude demonstrated by both-grade levels (between 60% and 70%). Also, the engineering content area was the only other content area to display an observable difference between students in the two grade levels along the *interest* and *value* dependent variables.

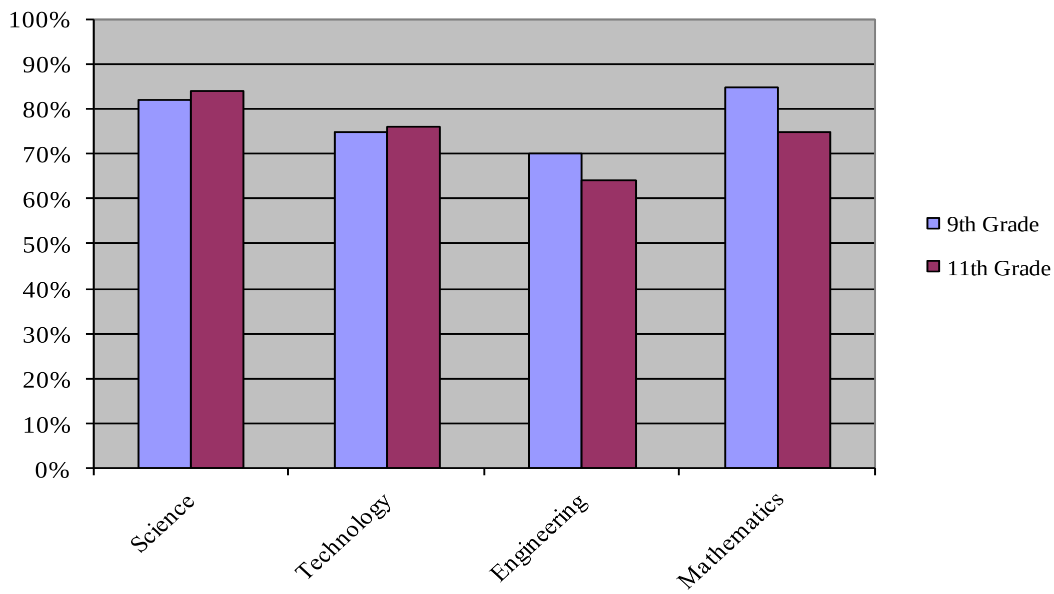


Figure 18. Percentage of Value for Each Grade Level for Each of the STEM Content Areas as Determined by Mean Scores

Though these values may not be statistically significant, it is interesting to see that student attitude for engineering may follow or be related to student attitude for mathematics. The major area of difference between students in the two grade levels was observed for the content area of mathematics. The ninth-grade students demonstrated a more positive attitude for the mathematics content area (between 74% and 85 %) when compared to the eleventh-grade students (between 60% and 75%). This incredible difference in overall attitude for mathematics was unexpected between students in the two grade levels.

Testing for Assumptions

As done in the previous analyses of the independent variable of school, two assumptions were reviewed during the preceding analyses – normality and homogeneity of variance. The same procedures were performed for the independent variable of grade level to address the additional assumption of independence. The students were instructed by the researcher to complete the attitudinal packets at home and by themselves. Violation of this direction would remove a student's entry from the incentive raffle offered to each school. It was therefore assumed that the students completed each packet independently as they were directed by the researcher. Review of the instruments while collecting the data also provided no clear indication of collaborative work by the students from either grade level.

The Levene's test was used to check for homogeneity of variance (homoscedasticity). Violation of homogeneity can lead to an increase of Type I or Type II errors. Based on this analysis, the dependent variable of *value* for the content of mathematics indicated a significant relationship ($p < .05$) and therefore a violation of homogeneity of variance. Review of the other levels of dependent variables (*interest* and *ability*) indicated that the overall content area of mathematics did not share the lack of variance between students in each the two grade levels as it was experienced for the dependent variable of *value*. If the dependent variable of *value* were to depict any statistical significance between the grade levels for the content area of mathematics, a Type I error could be possible. Careful consideration had to be taken before making any assumptions regarding this variable and its possible significance between the grade levels.

Dependent variable	Levene statistic	*df1*	*df2*	Sig.
Interest for all STEM content areas	2.725	1	142	.101
Interest for the content area of science	.116	1	142	.734
Interest for the content area of technology	1.852	1	142	.176
Interest for the content area of engineering	.286	1	142	.594
Interest for the content area of mathematics	.043	1	142	.835
Ability for all STEM content areas	5.540	1	142	.020*
Ability for the content area of science	.038	1	142	.846
Ability for the content area of technology	3.215	1	142	.075
Ability for the content area of engineering	.113	1	142	.737
Ability for the content area of mathematics	.942	1	142	.333
Value for all STEM content areas	.779	1	142	.379
Value for the content area of science	.051	1	142	.822
Value for the content area of technology	.553	1	142	.458
Value for the content area of engineering	.211	1	142	.647
Value for the content area of mathematics	6.902	1	142	.010*

* Indicates significance and possible violation of homogeneity, $p < .05$

Table 45. Tests for Homogeneity of Variance for the Independent Variable of Grade Level

A second violation was indicated by the dependent variable of *ability* for all STEM content areas. Although this level was deemed significant ($p = .020$), review of each of the STEM content areas, individually, indicated a strong dimension of equal variance between grade levels. Science content area indicated some concern (.075) and could explain some of the significance indicated by collection of STEM content areas for the *ability* dependent variable. Again, careful considerations for the possible homogeneity violations were performed prior to producing final statements regarding possible significance between the grade levels. Another assumption that still needed to be addressed is that of normality. Levene's test is not robust to conditions of non-normality.

The assumption of a normal distribution was verified by review of the frequency distributions and statistical procedures. Review of the frequency distributions indicated negatively skewed distributions for the majority of the dependent variables. Additional statistical procedures were also performed because of the unequal and low number of students in the sample from each grade level – the Kolmogorov-Smirnov and Shapiro-Wilk tests.

Upon review of the tests, it was determined that the majority of the distributions were not normally distributed ($p < .05$). Both test procedures were reviewed to draw this conclusion. The only exception to this condition was found for the content area of technology for both of the dependent variables of *interest* and *ability*. The normal distribution only applied to the eleventh-grade students. Lilliefors significance correction was also provided for the Kolmogorov-Smirnov test. This correction allowed for the content areas of technology and engineering not to appear significant for violation of normality (see Table 46). However, the Lilliefors significance correction removed pertinent outliers from the data and thereby focused the distribution so that it may appear normal. Removal of data, given the small *n*, would greatly influence the remainder of the instrument review.

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Dependent variable	Grade level	Statistic	df	Sig.	Statistic	df	Sig.
Interest for all STEM content areas	Eleventh-grade	.179	61	.000	.937	61	.004
	Ninth-grade	.138	83	.001	.949	83	.003
Interest for the content area of science	Eleventh-grade	.193	61	.000	.862	61	.000
	Ninth-grade	.155	83	.000	.872	83	.000
Interest for the content area of technology	Eleventh-grade	.073	61	.200*	.968	61	.114
	Ninth-grade	.082	83	.200*	.952	83	.004
Interest for the content area of engineering	Eleventh-grade	.114	61	.046	.925	61	.001
	Ninth-grade	.076	83	.200*	.946	83	.002
Interest for the content area of mathematics	Eleventh-grade	.127	61	.016	.944	61	.008
	Ninth-grade	.168	83	.000	.870	83	.000
Ability for all STEM content areas	Eleventh-grade	.189	61	.000	.902	61	.000
	Ninth-grade	.166	83	.000	.925	83	.000
Ability for the content area of science	Eleventh-grade	.145	61	.003	.895	61	.000
	Ninth-grade	.135	83	.001	.904	83	.000
Ability for the content area of technology	Eleventh-grade	.099	61	.200*	.963	61	.061
	Ninth-grade	.085	83	.200*	.964	83	.020
Ability for the content area of engineering	Eleventh-grade	.091	61	.200*	.955	61	.024
	Ninth-grade	.081	83	.200*	.964	83	.020
Ability for the content area of mathematics	Eleventh-grade	.125	61	.018	.915	61	.000
	Ninth-grade	.175	83	.000	.850	83	.000
Value for all STEM content areas	Eleventh-grade	.200	61	.000	.874	61	.000
	Ninth-grade	.127	83	.002	.927	83	.000
Value for the content area of science	Eleventh-grade	.182	61	.000	.838	61	.000
	Ninth-grade	.180	83	.000	.840	83	.000
Value for the content area of technology	Eleventh-grade	.116	61	.039	.936	61	.003
	Ninth-grade	.111	83	.013	.928	83	.000
Value for the content area of engineering	Eleventh-grade	.093	61	.200*	.938	61	.004
	Ninth-grade	.132	83	.001	.918	83	.000
Value for the content area of mathematics	Eleventh-grade	.184	61	.000	.889	61	.000
	Ninth-grade	.216	83	.000	.780	83	.000

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Table 46. Tests for Normality for the Independent Variable of Grade Levels

The lack of normality decreases the robustness of the Levene's test for homogeneity of variance and may increase the opportunity for Type I errors for all dependent variables and associated content areas. The violation of the normality assumption suggested certain concerns regarding the samples. These concerns are shared with those previously experienced reviewing the independent variable of school. The concerns include sample bias, population distribution, and positively focused test items. The violation of these assumptions, in addition to unequal and small *n*'s, required the use of non-parametric analysis procedures. Both parametric and non-parametric analyses were applied to the grade level comparison data. It was anticipated that using both analyses would aid in clearly identifying any demonstrated significant differences between students in the two grade levels.

Analysis of Variance

The multivariate tests did not identify any statistically significant relationships between the independent variable of grade level and the identified dependent variables (see Table 47). The univariate analysis demonstrated statistically significant relationships for the content area of mathematics (see Table 48). The statistical significance was demonstrated for each of the dependent variables, however at different alpha levels: *interest* ($F = 13.69$, $p = .000$), *ability* ($F = 4.01$, $p = .047$), and *value* ($F = 9.24$, $p = .003$). As previously suggested, the ninth-grade level students' exhibited higher mean scores for each of the dependent variables for the mathematics content area when compared to the eleventh-grade level students' mean scores. The Kruskal-Wallis test was utilized due to the violations of normality and homogeneity (specifically regarding mathematics content area) as previously discussed. The Kruskal-Wallis test results matched the results of the univariate analysis for the independent variable of grade level regarding the content area of mathematics (see Table 49).

Effect		Value	*F*	Hyp. *df*	Error *df*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed power
Grade level	Pillai's Trace	.14	1.71	12	125	.072	.141	20.50	.841
	Wilks' Lambda	.86	1.71	12	125	.072	.141	20.50	.841
	Hotelling's Trace	.16	1.71	12	125	.072	.141	20.50	.841
	Roy's Larget Root	.16	1.71	12	125	.072	.141	20.50	.841

Table 47. Multivariate Test for the Independent Variable of Grade Level

Content area	Dependent variable	Mean Squared	*df*	*F*	Sig.	Partial Eta Squared	Observed power
Science	Interest	31.60	1	.50	.480	.004	.108
	Ability	1.89	1	.08	.777	.001	.059
	Value	9.20	1	.25	.621	.002	.078
Technology	Interest	2.46	1	.05	.828	.000	.055
	Ability	14.49	1	.62	.432	.005	.123
	Value	4.14	1	.12	.734	.001	.063
Engineering	Interest	133.83	1	2.26	.136	.016	.320
	Ability	.48	1	.019	.892	.000	.052
	Value	142.41	1	2.82	.095	.020	.385
Mathematics	Interest	876.74	1	13.52	.000***	.090	.955
	Ability	153.28	1	5.31	.023*	.038	.628
	Value	397.63	1	10.22	.002**	.070	.888

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 48. Univariate Tests for the Independent Variable of Grade Level by content area by Interest, Ability, and Value

All dependent variables for the content area of mathematics were demonstrated as statistically significant (p < .05). The statistical significance from both of the parametric and non-parametric analyses aligns with the observations made during the mean comparisons performed prior to the data analysis.

Content area	Dependent variable	Chi-squared	df	Asymp. Sig
Science	Interest	.11	1	.743
	Ability	.05	1	.828
	Value	.06	1	.804
Technology	Interest	.16	1	.690
	Ability	.14	1	.708
	Value	.13	1	.720
Engineering	Interest	4.14	1	.042*
	Ability	.62	1	.431
	Value	4.98	1	.026*
Mathematics	Interest	13.38	1	.000***
	Ability	5.99	1	.014*
	Value	11.36	1	.001**

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 49. Kruskal-Wallis Test for the Independent Variable of Grade Level by content area by Interest, Ability, and Value

Careful attention must still be taken regarding implications of the statistical significance due to the violations of normality and homogeneity of variance from the utilized samples. Also identified as significant were differences for the content area of engineering for the dependent variables of *interest* and *value*. The significance of engineering content area for the two dependent variables was not indicated during the univariate analysis nor was it indicated during the mean comparison produced at the beginning of the data analysis. Provided the lack of supporting evidence from other analyses and the associated violations of normality regarding the engineering content area, this statistical significance produced by the Kruskal-Wallis test was not considered vital to the purpose of this study.

Summary of the Analysis – Grade Level

It was hypothesized that a statistically significant difference would be ascertained between the ninth-grade students and eleventh-grade students' attitudes toward STEM. This hypothesized difference would indicate that students at the eleventh-grade level would exhibit a more positive attitude toward STEM when compared to students at the ninth-grade level. This hypothesis was not supported by the analysis of the data. In fact, the only statistical significance found suggested that the ninth-grade level students' demonstrated more positive attitudes for the content area of mathematics when compared to the eleventh-grade students.

Gender

It was hypothesized that male students would exhibit a more positive attitude toward STEM than female students (Hypothesis C, H_1c). This difference in gender reflects an unfortunate reality regarding the content areas of STEM. Though, the number of females invested toward STEM education and STEM careers have improved over the years, a large gap still exists between the number of men and women within the fields. It was anticipated that male students would produce higher mean scores on the student attitude toward STEM instrument than female students.

A total of 71 male students and 73 female students provided completed instruments from both school samples. The data collected was again reviewed for each of the associated STEM content areas as well as the identified dependent variable levels:

interest, ability, and *value*. The estimated marginal means demonstrated some expected gender differences for each of the dependent variable.

Interest Mean Scores

The male students (*M* = 105.38, *SD* = 23.41) demonstrated a higher mean scores for the dependent variable of *interest* when compared to the mean scores from the female students (*M* = 95.42, *SD* = 15.17) for all STEM content areas. The difference between the students mean scores was larger than other comparisons previously reviewed, indicating a possible significant difference between the two genders. The highest obtainable score for this dependent variable was 144 – 9 items for all content areas with the highest possible score of 4 for each item. Given this range, the students mean scores demonstrated a level of *interest* at approximately 73% for the male students and 66% for the female students for all STEM content areas.

Gender	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male students	28.42	7.75	26.49	8.05	25.20	8.78	25.27	8.45
Female students	27.45	8.35	23.36	6.11	19.96	7.39	24.66	8.91

Note: Mean scores and standard deviations are based on a 36 point scale specific to the interest dependent variable.

Table 50. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Interest

Review of each of the STEM content areas indicated that the male students produced higher mean scores for all of the STEM content areas. The mean score differences varied for each of the STEM content areas; ranging from a mean score difference as small as .61 (mathematics) to a difference as large as 5.24 (engineering) between the two genders. Science and mathematic content areas did not display large mean differences between the two genders for the dependent variable of *interest*. Both content areas remained well below 1 point of difference between the provided mean scores (see Table 50).

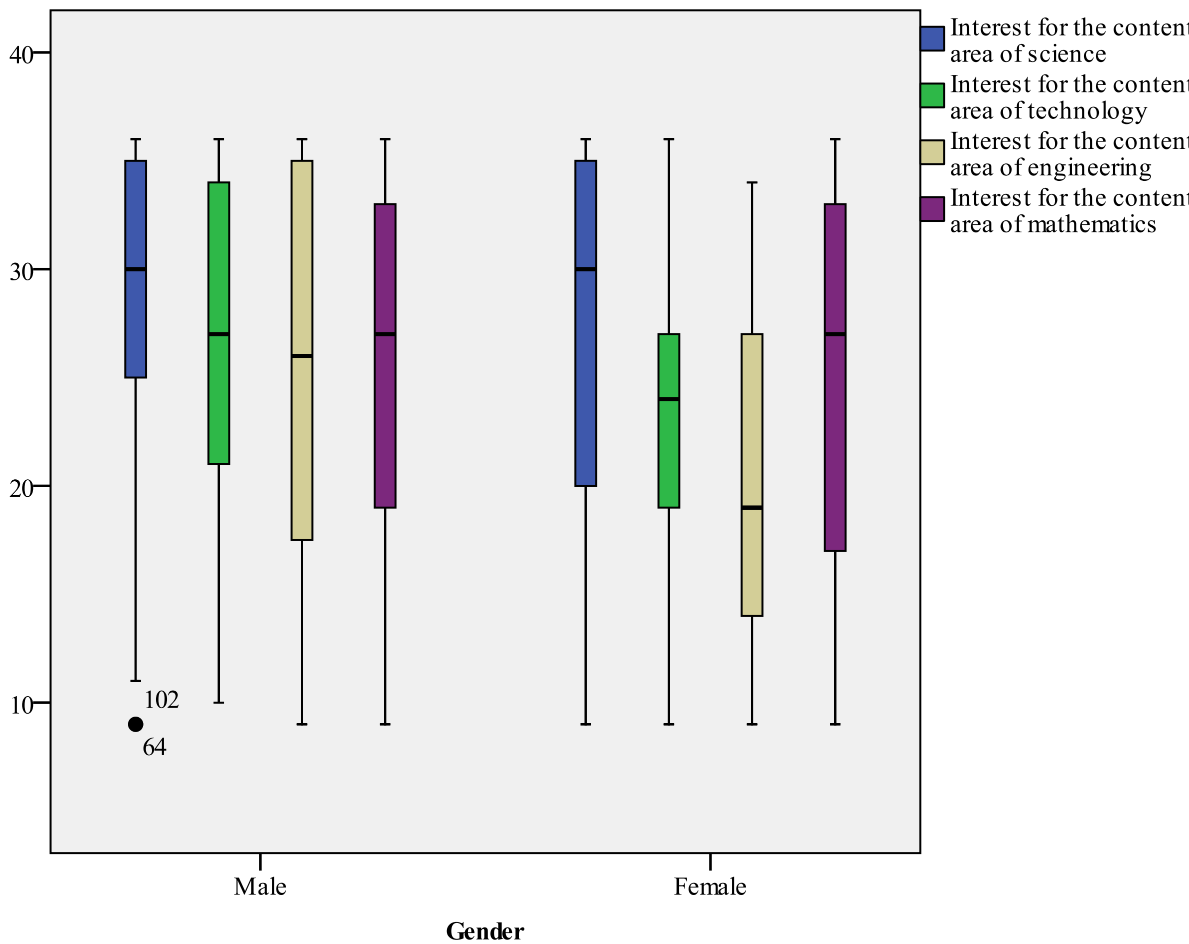


Figure 19. Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Interest

Technology and engineering content areas displayed the largest mean score differences between the two genders for the dependant variable of *interest*. The male students produced a mean score of 26.49 (*SD* = 8.05) and the female students produced a mean score of 23.36 (*SD* = 6.11) for the content area of technology, a difference of 3.13 points. The male students produced a mean score of 25.20 (*SD* = 8.78) and the female students produced a mean score of 19.96 (*SD* = 7.39) for the content area of engineering, a difference of 5.24 points. These mean scores differences for the technology and engineering content areas were expected to be statistically significant.

As previously stated, the total STEM content area level of *interest* for the male students was approximately 73% and for the female students was approximately 66% across all STEM content areas – both considered to be moderately positive. The individual content areas for the *interest* dependent variable had a highest obtainable score of 36 – 9 items with the highest possible score of 4 for each item. Figure 20 shows the percentages of each content area and gender as they were indicated by the mean scores demonstrated in Table 50.

The percentages of *interest* ranged between 90% and 64% for the two genders. Science and mathematics content area displayed almost equal levels of *interest* for both genders. Technology and engineering content areas demonstrated higher levels of *interest* provided by the male students when compared to the female students. The results demonstrated here are not necessarily surprising regarding gender interests for the STEM content areas. In fact, these results offer a sense of validity to the student attitude toward

STEM instrument regarding measurement of differences that may exist in an educational environment.

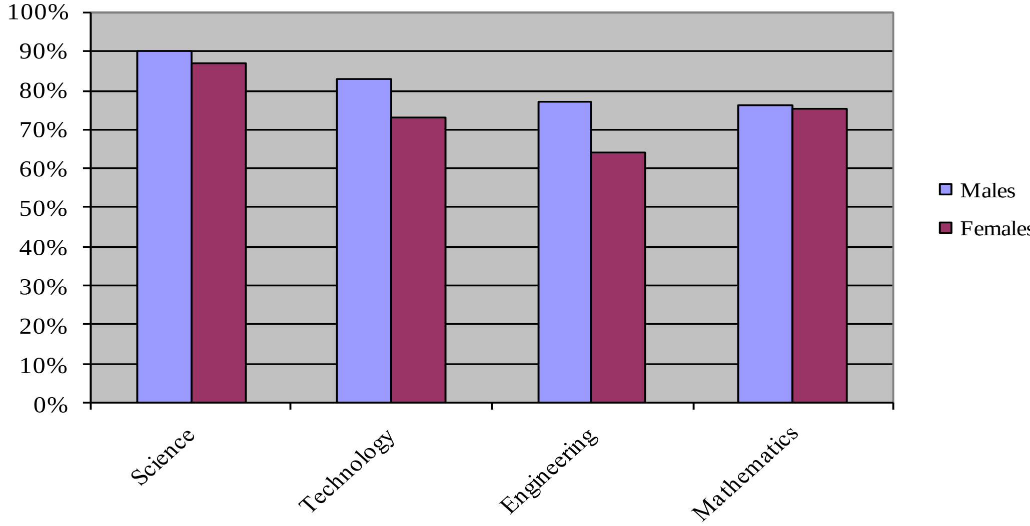


Figure 20. Percentage of Interest for Each Gender for each of the STEM Content Areas as Determined by Mean Scores

Ability Mean Scores

The dependent variable of *ability* demonstrated a higher mean score from the male students (M = 71.41, SD = 13.78) when compared to the mean score from the female students (M = 63.15, SD = 10.26) for all STEM content areas. The difference between the mean scores was equally as large as the previous dependent variable of *interest* and should indicate a possible significant difference between the two genders. The highest obtainable score for this dependent variable was 96 – 6 items for all content areas with the highest possible score of 4 for each item. Given this range, the mean scores of the gender independent variable demonstrated a level of *ability* at approximately 74% for the male students and 66% for the female students for all STEM content areas.

Review of each of the STEM content areas revealed that the male students produced higher mean scores for the *ability* dependent variable for all of the STEM content areas. The mean score differences varied for the STEM content areas, ranging from a mean difference as small as .85 (mathematics) to a difference as large as 3.51 (engineering). Science and mathematic content areas did not display large mean differences between the two genders across the dependent variable of *ability*. Both content areas demonstrated less than 2 points of difference between the provided mean scores (see Table 51).

Gender	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male students	19.20	4.66	17.46	4.74	16.30	5.39	18.45	5.53
Female students	17.73	5.23	15.03	4.94	12.79	4.89	17.60	5.83

Note: Mean scores and standard deviations are based on a 24 point scale specific to the ability dependent variable.

Table 51. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Ability

Technology and engineering content areas displayed the largest mean score differences between the two genders. The male students produced a mean score of 17.46 (*SD* = 4.74) and the female students produced a mean score of 15.03 (*SD* = 4.94) across the content area of technology, a difference of 2.43 points. The male students produced a mean score of 16.30 (*SD* = 5.39) and the female students produced a mean score of 12.79 (*SD* = 4.89) for the content area of engineering, a difference of 3.51 points. These mean scores differences for the technology and engineering content areas were expected to be significant.

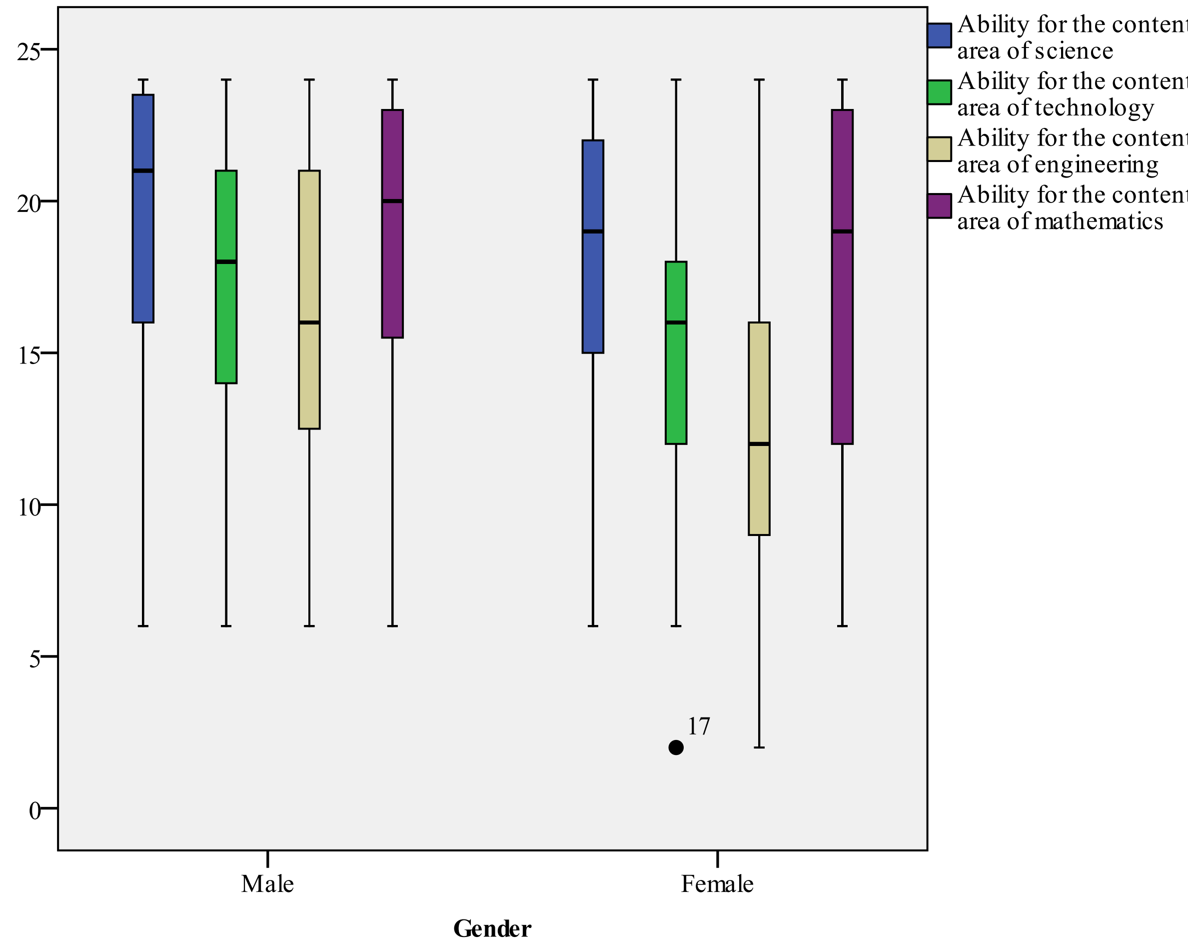


Figure 21. *Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Ability*

As previously stated, the total STEM content area level of *ability* for the male students was approximately 74% and for the female students was approximately 66% for all STEM content areas – considered to be moderately positive. The individual content areas for the *ability* dependent variable had a highest obtainable score of 24 – 6 items with the highest possible score of 4 for each item. Figure 22 shows the percentages of each content area and gender as they were indicated by the mean scores demonstrated in Table 51.

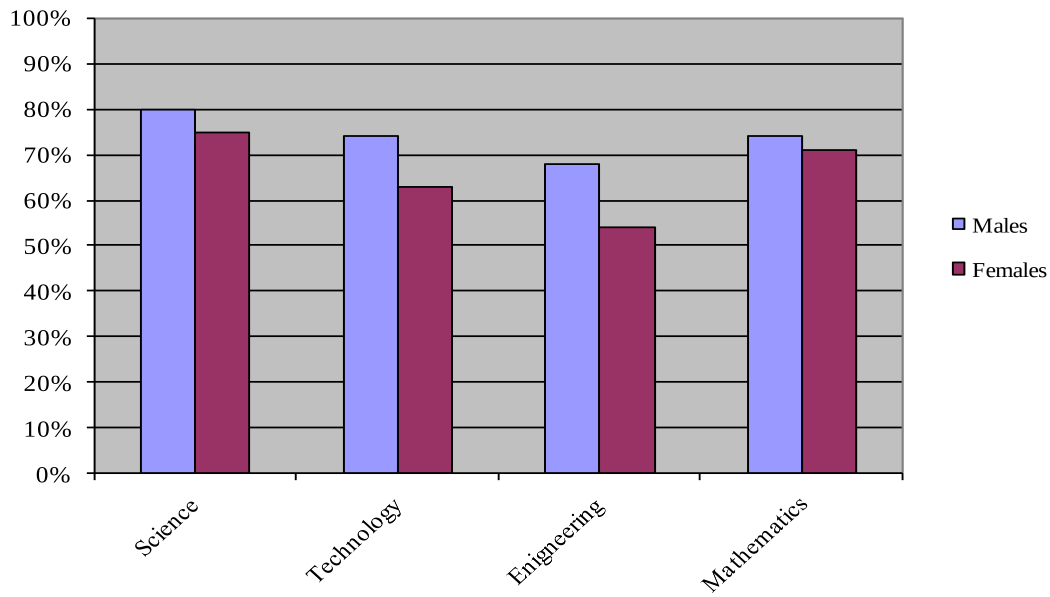


Figure 22. Percentage of Ability for each Gender for each of the STEM Content Areas as Determined by Mean Scores

The percentages of *ability* ranged between 80% and 54% for the two genders. Mathematics content area displayed almost equal levels of *ability* for both genders. Science content area also demonstrated a close association between the two genders regarding *ability*; however, overall percentages were slightly greater from the male students. Male students demonstrated higher levels of *ability* for the technology and engineering content areas when compared to the female students. The results revealed here are not necessarily surprising regarding gender perceived abilities toward the STEM content areas, especially regarding the significance demonstrated for the technology and engineering content areas.

Value Mean Scores

Male students (*M* = 102.59, *SD* = 19.56) demonstrated a higher mean scores for the dependent variable of *value* when compared to the mean score from the female students (*M* = 93.42, *SD* = 16.14) for all STEM content areas. The difference between the mean scores was equally as large as the previous two dependent variables; it should indicate a significant difference between the two genders. The highest obtainable score for this dependent variable was 128 – 8 items for all content areas with the highest possible score of 4 for each item. Given this range, the mean scores of gender demonstrated a level of *value* at approximately 80% for the male students and 73% for the female students for all STEM content areas.

Gender	Content area							
	Science		Technology		Engineering		Mathematics	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male students	26.58	6.16	25.55	6.12	23.85	7.62	26.62	6.62
Female students	26.23	6.12	22.51	5.97	19.27	7.26	25.42	6.54

Note: Mean scores and standard deviations are based on a 32 point scale specific to the value dependent variable.

Table 52. Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Value

Review of each of the STEM content areas demonstrated that the male students produced higher mean scores for the *value* dependent variable across all of the STEM content areas. The mean score differences varied for the STEM content areas, ranging from a mean score difference as small as .35 (science) to a difference as large as 4.58 (engineering). Science and mathematic content areas did not display large mean score differences between the two genders across the dependent variable of *value*.

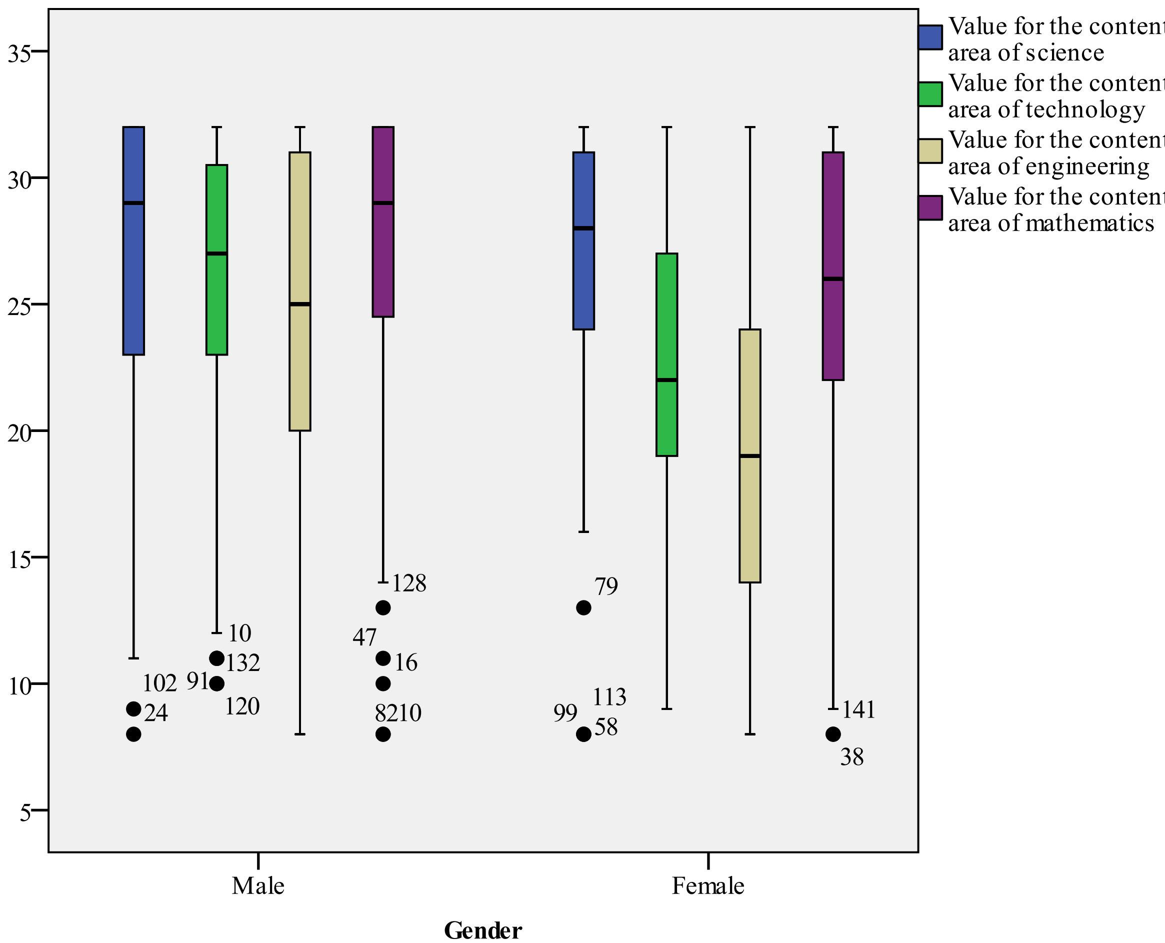


Figure 23. Boxplots of Mean Scores and Standard Deviations for STEM Content Areas for the Dependent Variable of Value

Both content areas demonstrated less than 1.5 points of difference between the provided mean scores (see Table 52). The technology and engineering content areas displayed the largest mean differences between the two genders. The male students produced a mean score of 25.55 (*SD* = 6.12) and the female students produced a mean score of 22.51 (*SD* = 5.97) for the content area of technology, a difference of 3.04 mean score points. The male students produced a mean score of 23.85 (*SD* = 7.62) and the female students produced a mean score of 19.27 (*SD* = 7.26) for the content area of engineering, a difference of 4.58 mean score points. These mean scores differences for the technology and engineering content areas were expected to be significant.

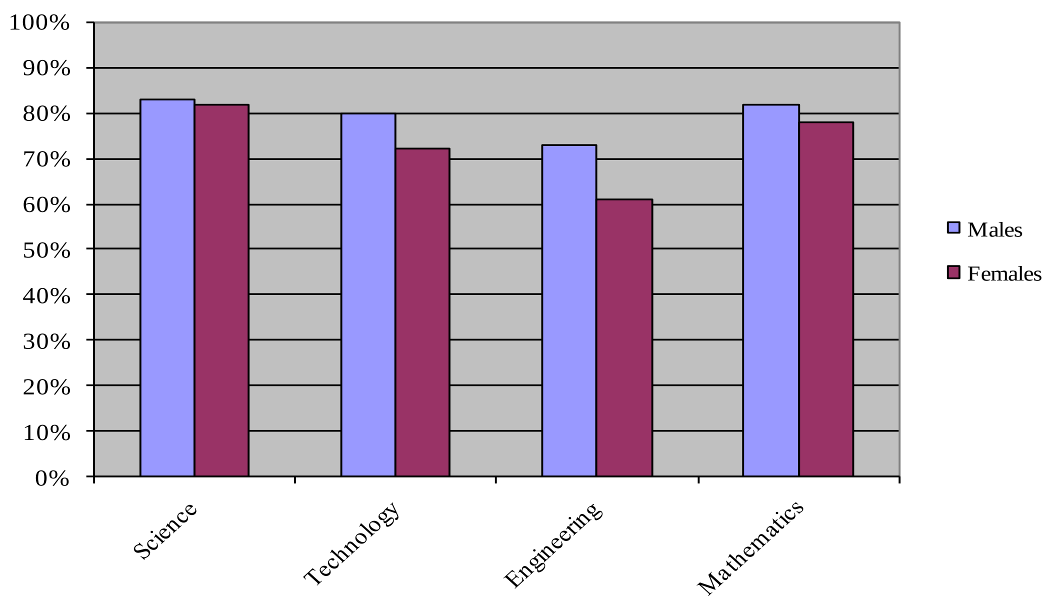


Figure 24. Percentage of Interest for each Gender for each of the STEM Content Areas as Determined by Mean Scores

As previously stated, the total STEM content area level of *value* for the male students was approximately 80% and for the female students was approximately 73% for all STEM content areas – considered to moderately positive. The individual content areas for the *value* dependent variable had a highest obtainable score of 32 – 8 items with the highest possible score of 4 for each item. Figure 24 shows the percentages of each content area and gender as they were indicated by the mean scores demonstrated in Table 52.

The percentages of *value* ranged between 83% and 61% for the two genders. Science and mathematics content areas displayed almost equal levels of *value* for both genders. Male students demonstrated higher levels of *value* for the technology and engineering content areas when compared to the female students. The results demonstrated here are not necessarily surprising regarding gender *values* toward the STEM content areas, especially regarding the significance demonstrated for the technology and engineering content areas.

At this point trends were observed for the four content areas of STEM and student overall attitudes toward STEM. Students of the two genders displayed similar levels of attitude for the science and mathematics content areas. The science content area retained the highest percentage of positive attitude demonstrated by the student's mean scores (between 75% and 90%). This is consistent for both genders. Mathematics follows closely behind, retaining the second highest overall percentage of positive attitude (between 71% and 82%).

The major areas of difference for the two genders were observed for the content areas of technology and engineering. The male students demonstrated a more positive attitude toward the technology content area (between 74% and 83 %) when compared to the female students (between 63% and 73%). The males continued to demonstrate a more positive attitude toward engineering content area (between 68% and 73%) when compared to the female students (between 54% and 64%).

The student attitude toward STEM instrument was been successful at measuring gender differences between provided by the two samples for this study. This sort of construct validity will only help the continued development of the instrument for future use. Of special note is the percentages provided by the two genders and for the STEM content areas. Though these differences are not surprising to most professionals involved with STEM and STEM education, what is surprising is how positive the attitude percentages demonstrated by the female students were.

Testing for Assumptions

Two assumptions were reviewed; normality and homogeneity of variance. Additionally, the assumption of independence was concluded prior to the official data analysis. The students were instructed by the researcher to complete the attitudinal packets at home and by themselves. Violation of this direction would remove a student's entry from the incentive raffle offered to each school. It was therefore assumed that the students completed each packet independently as they were directed by the researcher. Review of the instruments while collecting the data also provided no clear indication of collaborative work by the students from either gender group. The Levene's test was used to check for homogeneity of variance (homoscedasticity). Violation of homogeneity can lead to an increase of Type I or Type II errors. Based on this analysis, the dependent variable of *interest* for the content area of technology indicated a significant relationship ($p < .05$) and therefore a violation of homogeneity of variance.

Review of the other levels of dependent variables (*ability* and *value*) indicated that the overall content area of technology did not share the lack of variance between grade levels as it was experienced for the dependent variable of *interest*. If the dependent variable of *interest* were to depict any statistical significance between the gender groups for the content area of technology, a Type I error could be possible. Careful consideration had to be taken before making any assumptions regarding this variable and its possible significance between the male and female students.

Dependent variable	Levene statistic	*df1*	*df2*	Sig.
Interest for all STEM content areas	20.23	1	142	.000*
Interest for the content area of science	.80	1	142	.372
Interest for the content area of technology	8.48	1	142	.004*
Interest for the content area of engineering	2.91	1	142	.090
Interest for the content area of mathematics	.52	1	142	.472
Ability for all STEM content areas	13.27	1	142	.000*
Ability for the content area of science	.45	1	142	.503
Ability for the content area of technology	.04	1	142	.844
Ability for the content area of engineering	1.29	1	142	.257
Ability for the content area of mathematics	1.16	1	142	.284
Value for all STEM content areas	4.30	1	142	.040*
Value for the content area of science	.41	1	142	.521
Value for the content area of technology	.10	1	142	.750
Value for the content area of engineering	.11	1	142	.745
Value for the content area of mathematics	.000	1	142	.991

* Indicates significance and possible violation of homogeneity, $p < .05$

Table 53. Tests for Homogeneity of Variance for the Independent Variable of Gender

Other violations of homogeneity were indicated for each of the dependent variables for the overall content areas of STEM. Though each level was revealed to be statistically significant (see Table 53), review of each of the underlying STEM content areas individually for the dependent variables indicated a strong dimension of equal variance between male and female gender groups. Another assumption that still needed to be addressed is that of normality. Levene's test is not robust to conditions of non-normality.

The assumption of a normal distribution was verified by review of the frequency distributions and statistical procedures. Review of the frequency distributions indicated negatively skewed distributions for the majority of dependent variables for both mathematics and science content areas. A different distribution was demonstrated for the engineering and technology content areas. Male students indicated a negatively skewed distribution for technology and engineering content areas for most dependent variables. Female students indicated a normal distribution for the engineering and technology content areas for most dependent variables. Additional statistical procedures were also performed because of the unequal and low number of students in the sample from each gender; the Kolmogorov-Smirnov and Shapiro-Wilk tests (see Table 54).

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Dependent variable	Grade level	Statistic	df	Sig.	Statistic	df	Sig.
Interest for all STEM content areas	Female	.176	73	.000	.923	73	.000
	Male	.117	71	.018	.954	71	.011
Interest for the content area of science	Female	.153	73	.000	.875	73	.000
	Male	.164	71	.000	.865	71	.000
Interest for the content area of technology	Female	.075	73	.200*	.988	73	.716
	Male	.135	71	.003	.914	71	.000
Interest for the content area of engineering	Female	.119	73	.012	.939	73	.002
	Male	.135	71	.003	.914	71	.000
Interest for the content area of mathematics	Female	.139	73	.001	.900	73	.000
	Male	.117	71	.017	.925	71	.000
Ability for all STEM content areas	Female	.207	73	.000	.901	73	.000
	Male	.133	71	.003	.925	71	.000
Ability for the content area of science	Female	.117	73	.015	.909	73	.000
	Male	.163	71	.000	.890	71	.000
Ability for the content area of technology	Female	.101	73	.065	.974	73	.144
	Male	.104	71	.056	.950	71	.007
Ability for the content area of engineering	Female	.112	73	.023	.971	73	.096
	Male	.104	71	.054	.947	71	.005
Ability for the content area of mathematics	Female	.165	73	.000	.889	73	.000
	Male	.171	71	.000	.864	71	.000
Value for all STEM content areas	Female	.213	73	.000	.868	73	.000
	Male	.112	71	.027	.926	71	.000
Value for the content area of science	Female	.172	73	.000	.839	73	.000
	Male	.200	71	.000	.832	71	.000
Value for the content area of technology	Female	.073	73	.200*	.969	73	.073
	Male	.146	71	.001	.867	71	.000
Value for the content area of engineering	Female	.078	73	.200*	.954	73	.009
	Male	.171	71	.000	.884	71	.000
Value for the content area of mathematics	Female	.157	73	.000	.872	73	.000
	Male	.208	71	.000	.792	71	.000

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Table 54. Tests for Normality for the Independent Variable of Gender

Upon review of the tests, it was determined that the majority of distributions were not normally distributed ($p < .05$) with exception for the female gender group for the content areas of technology and engineering. Both test procedures were reviewed to draw these conclusions. Lilliefors significance correction was also provided by the Kolmogorov-Smirnov test. This correction allowed for some of the male gender group to appear normally distributed for content areas of technology and engineering for the dependent variables of *interest* and *value*. However, the Lilliefors significance correction removed pertinent outliers from the data and thereby focused the distribution so that it may appear normal. Again, removal of data was not considered an option during this research study.

The lack of normality decreases the robustness of the Levene's test for homogeneity of variance and may increase the opportunity for Type I errors for the identified dependent variables and associated content areas. The violation of the normality assumption suggested certain concerns regarding the samples that were previously demonstrated. However, strong indications of homogeneity as well as normal distributions were demonstrated for the female gender group. For this reason, both parametric and non-parametric analyses had to be applied to the comparison data of the gender groups. It was anticipated that using both analyses would aid in clearly identifying any demonstrated significance between the two gender groups.

Analysis of Variance

The multivariate tests did not identify any statistically significant relationships between the independent variable of grade level and the identified dependent variables (see Table 55). The univariate analysis demonstrated statistically significant relationships for the content areas of technology and engineering. The statistical significance was demonstrated for each of the dependent variables, however at different alpha levels (see Table 56). As previously suggested the male gender group exhibited higher mean scores for each of the dependent variables for the technology and engineering content areas when compared to the female gender group mean scores. Gender was the only independent variable to provide statistical significance for the collective content areas for each of the dependent variables; *interest* (F = 7.17, p = .008), *ability* (F = 12.65, p = .001), and *value* (F = 7.07, p = .009).

The Kruskal-Wallis test was utilized due to the violations of normality and homogeneity as previously discussed. The Kruskal-Wallis test results matched the results of the univariate analysis for the independent variable of gender regarding the content areas of technology and engineering (see Table 57). All dependent variables for the content areas of technology and engineering were demonstrated at statistically significant (p < .05).

Effect		Value	F	Hyp. *df*	Error *df*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed power
Gender	Pillai's Trace	.14	1.73	12	125	.068	.142	20.76	.847
	Wilks' Lambda	.86	1.73	12	125	.068	.142	20.76	.847
	Hotelling's Trace	.17	1.73	12	125	.068	.142	20.76	.847
	Roy's Larget Root	.17	1.73	12	125	.068	.142	20.76	.847

Table 55. Multivariate Test for the Independent Variable of Gender

Content area	Dependent variable	Mean Squared	*df*	*F*	Sig.	Partial Eta Squared	Observed power
Science	Interest	45.57	1	.72	.396	.005	.135
	Ability	55.25	1	2.35	.127	.017	.331
	Value	8.03	1	.21	.644	.002	.074
Technology	Interest	310.60	1	6.02	.015*	.042	.683
	Ability	199.15	1	8.55	.004**	.059	.827
	Value	262.24	1	7.32	.008**	.051	.766
Engineering	Interest	622.47	1	10.49	.002**	.072	.895
	Ability	331.55	1	12.81	.000***	.086	.944
	Value	442.05	1	8.76	.004**	.061	.836
Mathematics	Interest	4.58	1	.07	.791	.001	.058
	Ability	7.41	1	.26	.613	.002	.079
	Value	41.73	1	1.07	.302	.008	.177

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 56. Univariate Tests for the Independent Variable of Gender by content area by Interest, Ability, and Value

Content area	Dependent variable	Chi-squared	df	Asymp. Sig
Science	Interest	.29	1	.590
	Ability	2.98	1	.084
	Value	.52	1	.472
Technology	Interest	7.22	1	.007
	Ability	7.97	1	.005
	Value	11.30	1	.001
Engineering	Interest	13.25	1	.000
	Ability	15.19	1	.000
	Value	13.56	1	.000
Mathematics	Interest	.16	1	.689
	Ability	.55	1	.458
	Value	2.20	1	.138

Table 57. Kruskal-Wallis Test for the Independent Variable of Gender by content area by Interest, Ability, and Value

The statistical significance from both of the parametric and non-parametric analyses aligns with the observations made during the mean comparisons produced prior to the data analysis. Careful attention must still be taken regarding implications of the statistical significance due to the violations of normality and homogeneity of variance from the utilized samples, especially for the male gender group.

Summary of the Analysis: Gender

It was hypothesized that a statistically significant difference would be ascertained between the male gender and female gender students' attitudes toward STEM. This hypothesized difference would indicate that male students would exhibit a more positive attitude toward STEM when compared to female students. This hypothesis was supported by the analysis of the data for both the engineering and technology content areas.

Summary of Data Analysis

As derived from the analyses conducted for the purposes of this study, the following results were composed after review of the objectives of the study and proposed research hypotheses:

1. Levels of student attitude were accurately defined and identified through review of pertaining literature, utilization of panel of experts, as well as appropriate statistical analysis (Objective #1a). Three levels of attitude were well supported by the applied analyses. The initial analyses demonstrated the foundational construct and content validity for the student attitudinal instrument. They were identified as *interest, ability,* and *value*.
2. Items required to address each category of student attitude were defined and identified through review of pertaining instruments, panel of experts, student focus group, and appropriate statistical analysis (Objective #1b). The collection of

items established for this study was well supported by the applied analyses along each of the attitudinal categories for the STEM content areas. The combined analyses applied to the instrument items provided strong indications of reliability.

3. Reliability coefficients collected from the applications of the two versions of the student attitude toward STEM instrument indicated Cronbach's alpha scores above what was anticipated based on established attitudinal instruments (Objective #1c). An average reliability coefficient of .92 alpha was the derived from the final application of the attitudinal instrument, far exceeding the .70 alpha anticipated from the established research. The Pearson product moment correlation between the student attitude toward STEM instrument and the SEMDIFF indicated an overall moderately positive significant relationship between the two instruments (r = .63, p = .000). The student attitude toward STEM instrument utilized during the pilot study also indicated a stronger reliability coefficient than the SEMDIFF attitudinal instrument (.77 alpha overall). This provided the student attitude toward STEM instrument used for the pilot study with a viable source of concurrent validity (Objective #1c).
4. Students enrolled in a STEM-based high school program did not exhibit a statistically significant more positive attitude toward STEM when compared to students enrolled in a college-preparatory high school program (Objective #2, Hypothesis A). Conversely, the college-preparatory program did exhibit a statistically significant more positive student attitude toward STEM for the content area of mathematics. The null hypothesis was retained.

5. Students in the eleventh-grade level did not exhibit a statistically significant more positive attitude toward STEM when compared to ninth-grade level students (Objective #2, Hypothesis B). Conversely, the ninth-grade level students exhibited a statistically significant more positive attitude toward STEM for the content area of mathematics when compared to the eleventh-grade level students. The null hypothesis was retained.
6. Male students did posses a statistically significant more positive attitude toward STEM when compared to female students (Objective #2, Hypothesis C). This statistical significance represents a further example of construct validity for the revised student attitude toward STEM instrument. The null hypothesis was rejected and the proposed hypothesis was accepted.

Chapter 4 Summary

Chapter 4 provided the methods and procedures utilized to review the student attitudinal instrument following the pilot study – the known group comparison (Phase III). Item analysis demonstrated and reinforced dependent variables demonstrated during the pilot study as well as those anticipated through review of related research and literature. Reliability coefficients produced by utilization of the Cronbach's alpha procedure indicated strong reliability for the revised instrument for all content areas. Further analyses included mean comparisons, frequency distributions, multivariate analysis, and parametric and non-parametric univariate analysis procedures for the varied independent variables sought. A concise summary of the overall research findings was also provided. Chapter 5 further concludes findings of the research study. Recommendations for future research and instrument refinement are also included.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to design, create, and revise a survey instrument capable of measuring high school student attitude toward the four content areas of STEM – science, technology, engineering, and mathematics. This chapter includes a review of the objectives of the study as well as the research hypotheses. Results of reliability and validity procedures will be discussed in detail regarding each of the proposed hypotheses. The chapter will conclude with recommendations for future applications and refinement for the student attitude toward STEM instrument.

Objectives of the Study

The principal objectives of this study were addressed as follows:

1. Construct a new attitudinal instrument.

After extensive review of the existing research and instruments attributed to the measurement of attitude, it was determined that a new instrument had to be developed. Each instrument had established its own definition of attitude; the researchers' definitions were reflected in each instrument's purpose. Therefore, defining and applying a definition of attitude for an instrument to measure attitude was found to be dependent on a collection of variables and conditions that exist in any one given situation.

a. To create and identify categories specific to student attitude toward STEM based on review of research and literature.

The CBAM and the TEOII provided the inspiration for the student attitude toward STEM instrument. The CBAM provided a framework into how a person may change when they are exposed to a different program or situation. Traditionally, the CBAM was used for teachers in a professional development situation, but the instrument can and has been utilized in other varied applications with similar success. To focus the framework to a more student-centered attitudinal development, the TEOII was reviewed and utilized. The layout of the *affective* domain provided an outline that directly addressed the anticipated objectives of an educational program as a student becomes more invested toward an educational component. The inspiration provided by the combined review of these instruments allowed for the creation of the initial four attitudinal categories created for the pilot instrument – *awareness, ability, value,* and *commitment.*

The four initial attitudinal categories covered a wide spectrum of concerns regarding STEM and STEM education. *Awareness* was intended to assess initial student interest toward the four content areas. The same category also was intended to assess if the students were aware of what programs were available, an attribute later relocated to the demographic section of the instrument. *Ability* was intended to indicate how the students' perceived their own capability within each of the four content areas. *Value* was intended to identify to what extent the students found worth within each of the content areas. Finally, *commitment* was anticipated to indicate long-term interest toward each of the four content areas, whether it was career, college, or otherwise invested. These four attitudinal categories addressed some of the expectations and anticipated products of STEM-based programs.

An additional challenge to creating this attitudinal instrument was to address the concern of measuring four content areas within a single instrument and/or item. To create four separate tests for the students to complete would create additional concerns regarding measurement error as well as additional time to complete. The order in which the packets were completed in addition to the extended time to complete each packet may have a greatly influenced or changed the results. A new format was developed that would allow for all four content areas to be addressed simultaneously within a single instrument.

b. To create and identify items specific to each of the established attitudinal categories intended to measure student attitude toward STEM.

The instrument items were created by the researcher after an extensive review of existing attitudinal instruments and documentation. Traditional items as found on other attitudinal instruments were too specific and did not allow for equal weight along each of the four content areas. General items were created to allow equal weight for each of the content areas, thereby, attempting to avoid possible bias for any one content area over another. A collection of these items were submitted to a panel of experts for selection and possible recommendations. The combined input provided by the panel of experts allowed the researcher to assemble a final list of items. The list was again submitted to the panel of experts for final review prior to implementation in the pilot study. Once approved, the items were administered to a sample of high school students from a single high school. After collecting and coding the data, the items were subjected to a principal components analysis. The analysis demonstrated three principal components. They were identified by the researcher as *interest, ability,* and *value*. These components were comparable with theories demonstrated by the attitudinal categories created from the review of the research.

A student focus group was utilized to establish item clarity and appropriate scale coding following the pilot study (Phase II). Items that were designated as confusing or otherwise misinterpreted by the students were either revised or removed from the instrument prior to the known-group comparison (Phase III). The panel of experts was again used to review the items after suggested revisions were made to the collection of items. Once approved, the instrument was administered to two high schools with proposed varying educational environments, the known-group comparison study. A second principal components analysis was performed and three principal components were demonstrated. The researcher again identified the three principal components as *interest, ability,* and *value*. Review of the items and the item analyses suggested future revisions may be required prior to continued implementation.

c. To establish reliability and validity of the student attitude toward STEM instrument.

The Cronbach's alpha procedure was utilized to assess the degree of reliability obtained by student responses on the student attitudinal instrument. Reliability coefficients of the student attitudinal instrument were anticipated to be .70 or higher. The CBAM provided reliability coefficients that ranged between .45 and .83, as indicated by review of available research. Instruments in early stages of development are not projected to have strong reliability coefficients until they are further revised. Both the pilot study and known-group comparison study provided strong demonstrations of reliability as indicated by Cronbach's alpha procedure scores. The pilot test reliability coefficients ranged between .76 and .96 alpha – an average of approximately .88 alpha. The known-group comparison demonstrated stronger reliability coefficients ranging between .88 and .95 alpha – an average of approximately .92 alpha. The high alpha coefficients were consistent for all identified dependent variables and STEM content areas. The strong display of reliability indicates that the current application of the instrument is yielding consistent results. However, at this point, we can only assume that the items are consistently measuring attitude. The expert panel's review of the instrument and its associated items – in addition to the strong implications from the existing attitudinal research and literature – aid in the assumption of content validity.

Concurrent validity was recognized after review of the pilot study (Phase II) by comparing student responses on the student attitude toward STEM instrument to their responses on another attitudinal instrument – a semantic differential attitudinal instrument. The Semantic Differential (SEMDIFF) attitudinal instrument was utilized for its reliable and valid measurement of attitude as indicated by review of associated research. The SEMDIFF was also used for its ease and speed of completion. A SEMDIFF was developed and applied to each of the content areas of STEM. The mean scores from the SEMDIFF instrument were correlated with the mean scores from the student attitude toward STEM instrument developed for this study for each of the STEM content areas.

Both instruments were located within a single research packet and were filled out by the students at the same time.

The data from both instruments was subjected to the Pearson product moment correlation procedure. This correlation was done to establish concurrent validity of the student attitudinal instrument beyond that of face and content validity as previously discussed. The Pearson product moment procedure provided statistically significant correlations that were moderately positive between the two attitudinal instruments for all content areas. As previously indicated, this form of concurrent validity only applies to the student attitude toward STEM instrument utilized during the pilot study and not the revised version utilized during the known-group comparison (Phase III). The student attitudinal instrument toward STEM demonstrated both reliability and validity verified by the collective analyses obtained from the single high school student sample collected during the pilot study – Phase II.

2. To test the validity of the instrument between groups of anticipated difference.

Following the known-group comparison, several analyses were performed using the collected data in addition to the item analysis. The data was divided into a collection of independent variable-based groups and compared by their mean scores demonstrated for the identified dependent variables and the associated content areas. These analyses were utilized to establish further construct validity based on anticipated differences between the measured groups. However, some surprising results were demonstrated between these groups as indicated by the data analysis.

a. To test mean scores between the STEM-based high school and college-preparatory high school students across all dependent variables and content areas.

It was anticipated that the STEM-based high school students would produce more positive attitudes toward STEM than students at a college-preparatory high school that does not purposefully focus its educational program on STEM and STEM education. Students in the schools did not demonstrate significant differences in attitude toward STEM for the majority of content areas. The only exception was for the content area of mathematics. For the mathematics content area, the college-preparatory high school students displayed a more positive student attitude toward STEM than the STEM-based high school students for each of the identified dependent variables: *interest*, *ability,* and *value*.

b. To test mean scores between the ninth-grade level and eleventh-grade level students across all dependent variables and content areas.

It was anticipated that students that were exposed to any variation of a STEM-based education for a longer duration would demonstrate a more positive attitude toward STEM. The comparison was performed between the ninth-grade level and the eleventh-grade level students from both high schools. As indicated from the analyses, the only statistical significance was demonstrated for the content area of mathematics in favor of the ninth-grade level students. The significance was consistent for all of researcher-identified dependent variables of attitude.

c. To test mean scores between male and female students across all dependent variables and content areas.

The variable of gender was the only independent variable to demonstrate an anticipated significant difference between groups. Male students demonstrated more positive attitudes toward STEM than female students. The statistically significant difference was specific to the content areas of engineering and technology. The difference was significant for all identified dependent variables. Science and mathematics content areas did not demonstrate a statistically significant difference between female and male students.

Discussion of the Hypotheses

As indicated by the objectives of the study and a complete review of the literature, the following hypotheses were formulated and examined. The following is a discussion of the findings and their implications for the student attitude toward STEM instrument.

H_1a: Students enrolled in a STEM-based college preparatory program will exhibit a more positive attitude toward STEM than students enrolled in a conventional college-preparatory program.

H_0a: Students enrolled in a STEM-based college preparatory program will not posses a more positive attitude toward STEM than students enrolled in a conventional college-preparatory program.

According to the results of the data analyses, the STEM-based high school students did not exhibit a statistically significant more positive attitude toward the content areas of STEM when compared to the college-preparatory high school students. This result did not support the proposed hypothesis. Therefore, the null hypothesis of no difference between the two schools had to be retained.

It was anticipated that the STEM-based high school students would provide a more positive attitude due to the programs specific focus and dedication toward STEM as indicated by its public documentation. This proposed difference would have provided an example of construct validity for the student attitude toward STEM instrument. Though this result was not anticipated, it was not believed to have negative implications for the student attitude toward STEM instrument. Variables or factors that could have influenced this outcome – positively or negatively – have not yet been identified or investigated.

Interestingly, a statistically significant more positive attitude was demonstrated by the college-preparatory high school students when compared to the STEM-based high school students for the content area of mathematics. Review of this analysis could allow for the determination that both high school programs support similar student positive attitudes for the content areas of science, technology, and engineering. Also, it may be determined that the college-preparatory high school is supporting a more positive student attitude for mathematics when compared to the STEM-based program students.

Assumptions of homogeneity and normality were both violated, specifically for the content area of mathematics. Generalization of the instrument results to a larger population was not the focus of this study nor this hypothesis. Future applications of the instrument with larger and more varied samples will address the concerns of homogeneity and normality more specifically.

H_1b: Students exposed to STEM education for a longer period of time (i.e., higher grade level) will exhibit a more positive attitude toward STEM than students enrolled for a shorter duration (i.e., lower grade level).

H_0b: Students exposed to STEM education for a longer period of time (i.e., higher grade level) will not exhibit a more positive attitude toward STEM than students enrolled for a shorter duration (i.e., lower grade level).

According to the results of the data analyses, the eleventh-grade level students did not exhibit a statistically significant more positive attitude for the content areas of STEM when compared to the ninth-grade level students. This result did not support the proposed hypothesis. Therefore, the null hypothesis of no difference between the two grade level students had to be retained.

It was anticipated that the eleventh-grade level students would provide a more positive attitude due to the extended exposure and experience with STEM content areas. This proposed difference would have provided an example of construct validity for the student attitude toward STEM instrument. Though this result was not anticipated, it was not believed to have negative implications for the student attitude toward STEM instrument. Like the previous hypothesis regarding school differences, variables or factors that could have influenced this outcome – positively or negatively – have not yet been identified or investigated.

Similar to the previous hypothesis (Hypothesis A, H_1a), an unexpected and opposite result was demonstrated by the analyses. A statistically significant more positive attitude was demonstrated by the ninth-grade level students when compared to the eleventh-grade level students for the content area of mathematics. Review of this analysis could allow for the determination that students at both-grade levels exhibit similar levels of attitude for the content areas of science, technology, and engineering. It could also be determined that the ninth-grade level students had more positive attitudes for STEM than the eleventh-grade level students for the content area of mathematics.

The assumption of homogeneity of variance was violated as demonstrated by the identified dependent variable of *value* for the content area of mathematics. This specific and singular violation of homogeneity was not demonstrated by any other identified dependent variable for any other content area. Normality was still violated by an overall negative skew of the distributions.

H_1c: Male students will exhibit a more positive attitude toward STEM than female students.

H_0c: Male students will not exhibit a more positive attitude toward STEM than female students.

According to the results of the data analyses, the male students indicated a statistically significant more positive attitude for STEM when compared to the female students. The statistical significance was demonstrated specifically for the content areas of technology and engineering. The results of the data analysis supported the proposed hypothesis for the content areas of technology and engineering, rejected the null, and therefore provided the student attitude toward STEM instrument with an example of construct validity.

It was anticipated that the male students would provide a more positive attitude for STEM and STEM education due to the gender bias that has been traditionally associated with the STEM content areas. Though not statistically significant, an unexpected and interesting result was revealed in the analyses. Male students did not depict a statistically significant more positive attitude for STEM for the content areas of science and mathematics. This would imply that male and female students do not differ significantly regarding their attitudes for these two content areas.

Assumptions of homogeneity of variance were only violated, as demonstrated by the dependent variable of *interest*, for the content area of technology. Normality was still violated by an overall negative skew of the distributions for the male students. The female students' responses on the instruments demonstrated primarily normal distributions. Females were the only sample to provide data consistent with normal distributions within the limitations of this study.

Recommendations

Based on the findings of this study, recommendations for further validation and/or research applications are as follows:

1. Repeat the study with a larger and more varied sample size.

Increasing the sample size by involving more high schools involving both conventional college-preparatory programs and STEM-based programs would aid in establishing further validity to the student attitude toward STEM instrument. A greater sample size reduces the sensitivity of the collected data. With a reduction of data sensitivity, varied results regarding principal component loadings as well as differences revealed by the univariate analyses may be identified. Also, a random selection of the pooled student responses from each high school program population could be utilized instead of having to use every completed instrument. This procedure would allow for equal *n*'s during the analyses as well a plausible representation of the overall population. The larger sample size from either high school program group would provide a more accurate distribution of the two groups and thereby determine if any transformations of data are required to ascertain normality. Larger samples may be obtained through cooperative research with local, state, or national agencies. Cooperation with existing studies that involve or are interested in attitudinal research will also be considered.

2. Longitudinal application of the instrument to previously assessed students.

Provided the sensitivity and large standard deviations indicated during the analyses in the study, longitudinal review of already assessed students may provide another example of instrument validity in the form of predictive validity. Students could be contacted in 2 years to re-take the instrument. Their results will be compared to their previous mean scores for any significant developments over time. Also, the then eleventh-grade students – ninth-grade students assessed in this study – could be compared with the scores of the previous eleventh-grade students used in this study. The same comparison could be performed between newly arriving ninth-grade students as well as the ninth-grade student scores presently obtained.

3. Individual student interviews following submission of the instrument.

A random selection of students should be selected after completing the student attitude toward STEM instrument. This additional qualitative analysis would be utilized to review the instrument as well as the student responses. The students will be asked a series of questions related to the identified dependent variables of STEM attitude. Questions and/or a script will be designed by a panel of experts experienced in qualitative analysis. The researcher will allow the students to expand on their responses during taped interview sessions. Reponses will be coded and compared to the students' responses on the instrument. Additional steps for item clarity and coding may also be taken during these interview sessions as deemed necessary.

4. Review of the combined influence of independent variables.

Review of the applied MANOVA procedure indicated that combinations of certain independent variables utilized in the study provided statistically significant results regarding student attitude for STEM. It was not the intention of this study to investigate identified relationships between independent variables. Future review of the MANOVA analyses will be performed following the conclusion of this study. Significant implications will be reported as is necessary for the development of the instrument.

5. Investigation of other possible independent variables.

Several other independent variables were collected during this initial study of the student attitude toward STEM instrument. The variables collected included grade point average, ethnicity, number of classes taken for each of the STEM content areas, and career interest. Several more were considered but not as of yet collected. Future versions of the instrument may include such items. Other possible independent variables can and will be considered, only after the instrument is further reviewed and has established greater indications of reliability and validity for the perceived population.

6. Maintain concurrent validity.

Concurrent validity was demonstrated during the pilot study comparison utilized in this research study. However, the main portion of the research study – Phase III – did not address or re-establish concurrent validity for the revised student attitude toward STEM instrument. The SEMDIFF attitudinal instrument was a sufficient example of a comparable attitudinal measurement for this level of exploratory instrument development. Future research intends to utilize more proficient attitudinal scales/instruments as they become available. Revisions of the instrument are probable; therefore concurrent validity will have to be re-established frequently during the development of the student attitude toward STEM instrument.

7. Explore applications of the student attitude toward STEM instrument.

The focus of the research study was to develop a student attitude toward STEM instrument. The instrument was created to provide concerned parties with a measurement of student attitudinal level regarding proposed STEM educational program's/product's effectiveness and how such educational programs/products can best be utilized and/or refined. Varied applications and interpretations of the student attitude toward STEM instrument were not yet considered due to the predominate focus on creating the instrument. However, once the student attitude toward STEM instrument is further developed; varied applications and interpretations will be explored. Possible explorations include single STEM content area measurement and analysis, instrument interpretation and scoring, and content area measurement outside of STEM.

8. Application of alternative analysis procedures.

The data analysis procedures applied during the research study were limited by the researcher to the principal components analysis, Cronbach's alpha, Pearson product moment correlation, and MANOVA and follow-up univariate procedures. These selected analysis procedures were employed based on review of previous instrument studies and other pertinent literature. Though these procedures were deemed appropriate for this phase of the exploratory study; as the development of the student attitude toward STEM instrument continues, other analysis procedures would be more suitable. Factor analysis, the Rasch model, and correlation matrixes are just a few examples of analytical procedures to be utilized in the future.

Chapter 5 Summary

This study was described as a critical tool for STEM education programs as well as the organizations that support them. The instrument was developed in attempt to indicate students' attitudes toward STEM so that educational institutions that are implementing a STEM-based program can ascertain if their program is having the desired influence on their students. Based on the results of this study, the instrument demonstrates early examples of reliability and validity.

The instrument was effective in identifying differences between male and female students. The instrument did not detect significant differences between the schools or the grade levels. The lack of detection of difference may not be a deficiency of the instrument, but could be due to sensitivity provided by small and exclusive samples. Another possible indication could be the actual lack of difference between the independent variable groups of school and grade level. As suggested, larger and more varied samples should provide enough information to resolve these concerns.

Further review of the instrument and its associated items will continue through the exploration of larger and varied samples. Undoubtedly, the instrument will change as more research is obtained. It is expected that the student attitude toward STEM instrument will be exposed to as much research and revisions as are available until it becomes an applicable and reliable attitudinal measurement device. An official timeline has not been established for completion of the instrument. Review of other attitudinal instruments revealed that the development and research required for a substantial attitudinal instrument is almost never complete and could continue on indefinitely. This study was an initial step toward what could be a lifelong development of an instrument to measure student attitude toward STEM. It was an imperative step in providing what could be a valuable tool for STEM-based educational programs as well as those organizations supporting them.

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APPENDIX A: INSTRUMENT COVER PAGE: INITIAL

WE NEED YOUR HELP!

The Ohio State University and your high school are trying to measure high school students' attitudes toward the subjects of science, technology, engineering and mathematics (STEM). We want your input! You are the focus and function of high schools, and your thoughts about these STEM subjects are as vital as the classes themselves. The information that you provide on this survey will aide in the development of a measurement device that will allow schools like yours to improve their programs to better meet the needs of students as well as local and national educational requirements.

This survey is COMPLETELY VOLUNTARY

Your responses on this survey will remain *CONFIDENIAL*. *NO ONE* in your school (teachers, administrators, or students) will see your responses on this survey. Participation in this study will have *NO EFFECT* on your academic standing or grades.

If you choose to participate, you will be entered into a raffle for a chance to win a…
$100 worth of Gift Cards to stores of your choosing*

(*Actual card will vary depending on availability)

To be entered into the raffle, you must complete all the paper work included in the packet provided to you. The items that must be returned are listed below:

- **Student permission form – Signed by you**
- **Parent permission form – Signed by your parent(s)/legal guardian(s)**
- **Student Attitude Survey – Correctly filled out**

If you return the packet and any of the above documents are either not correctly filled out or are missing completely, you will not be entered into the raffle. All documents are due on the date and time provided by the researcher when the packets were distributed.

NOTE: A small collection of students who complete the packet correctly may be contacted to participate in a small focus group. The purpose of this focus group is to make sure the survey and its questions were clear and easy to understand. Your actual responses on the survey will remain CONFIDENTIAL and are not a part of this focus group activity. Your participation in this focus group if contacted is VOLUNTARY and will have no influence upon your chances in the raffle or your standing in the school.

APPENDIX B: STUDENT ATTITUDE TOWARD STEM INSTRUMENT: INITIAL

Student attitude toward STEM
Initial Instrument Review

In cooperation with
THE OHIO STATE UNIVERSITY

Researchers:
Karen Zuga, Principal Investigator
Mark Mahoney, Co-investigator

IRB Protocol number: 2008B0295
IRB Protocol approval date: 1/18/2009

The following definitions are to clarify what is implied by each of the STEM subjects; science, technology, engineering, and mathematics. Please review these definitions provided before proceeding on to the survey.

Science:
The systematic observation of natural events in order to obtain facts about them and to formulate laws and principles based on these facts. Science is the organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation. There are several sections of the general body of knowledge relating to science; such as biology, physics, chemistry, geology, or astronomy. (Academic Press Dictionary of Science & Technology)

Technology:
Technology is the process by which humans modify nature to meet their needs and wants. Most people, however, think of technology in terms of its artifacts: computers and software, aircraft, pesticides, water-treatment plants, birth-control pills, and microwave ovens, to name a few. But technology is more than these tangible products. Technology includes the entire infrastructure necessary for the design, manufacture, operation, and repair of technological artifacts, from corporate headquarters and engineering schools to manufacturing plants and maintenance facilities. The knowledge and processes used to create and to operate technological artifacts -- engineering know-how, manufacturing expertise, and various technical skills -- are equally important part of technology. (National Academy of Engineering)

Engineering:
The profession of or work performed by an engineer. Engineers are problem solvers who search for quicker, better, and less expensive ways to use the forces and materials of nature to meet today's challenges. Engineering involves the knowledge of the mathematical and natural sciences (biological and physical) gained by study, experience, and practice that are applied with judgment and creativity to develop ways to utilize the materials and forces of nature for the benefit of mankind. (American Society for Engineering Education)

Mathematics:
Study of abstract patterns and relationships that results in an exact language used to communicate about them. Mathematics is also considered science of structure, order, and relation that has evolved from elemental practices of counting, measuring, and describing the shapes of objects. It deals with logical reasoning and quantitative calculation, and its development has involved an increasing degree of idealization and abstraction of its subject matter. (Webster-Merriam, Encyclopedia Britannica)

PART I
Demographic information
Address each question as indicated by the provided directions. Do not write your name on any of these pages.

Please fill in the one circle for each of the following areas:

Grade level:

9th	10th	11th	12th
◯	◯	◯	◯

Age (in years):

12	13	14	15	16	17	18	19
◯	◯	◯	◯	◯	◯	◯	◯

Gender:

Male	Female
◯	◯

Ethnicity:

Black	White	Asian	Hispanic
◯	◯	◯	◯

If other, please specify: ______________________

GPA:

<1.0	1.0 – 1.9	2.0 – 2.9	3.0 – 3.4	3.5 – 4.0
◯	◯	◯	◯	◯

Before moving on to **Part II**, please read the directions below:

Semantic Differential

On the next page of the packet you will find four concepts to be judged: science, technology, engineering, and mathematics. Under each concept will be a collection of scales. You will rate each concept along each of the underlying scales. Refer to the examples below:

SNOW						
bad	._______.	._______.	._______.	._______.	.___X___.	good

In this example, a student has indicated that SNOW is *very closely related* to one end of the scale, in this case GOOD.

SNOW						
hard	._______.	.___X___.	._______.	._______.	._______.	soft

In this second example, a student has indicated that SNOW is *somewhat related* to one end of the scale, in this case, HARD.

SNOW						
slow	._______.	._______.	.___X___.	._______.	._______.	fast

In this final example, a student has indicated that SNOW is *neutral,* suggesting that both sides of the scale are either *equally associated* or are *completely irrelevant* to the concept of SNOW.

IMPORTANT:

1. **Place your X in the middle of the spaces provided**
2. **Check every scale, do not omit any**
3. **Never place more than one X in each scale**
4. **Look at each concept/scale independently, do not go back and forth through items**
5. **Work quickly, your first and natural impression is what we are trying to measure. Do not try to 'over think' each scale.**

Part II begins on the following page.

Part II
Semantic differential

SCIENCE						
bad	.________.	.________.	.________.	.________.	.________.	good
like	.________.	.________.	.________.	.________.	.________.	hate
loathe	.________.	.________.	.________.	.________.	.________.	welcome
interesting	.________.	.________.	.________.	.________.	.________.	dull
pleasant	.________.	.________.	.________.	.________.	.________.	foul
optimistic	.________.	.________.	.________.	.________.	.________.	pessimistic
hard	.________.	.________.	.________.	.________.	.________.	soft
light	.________.	.________.	.________.	.________.	.________.	heavy
feminine	.________.	.________.	.________.	.________.	.________.	masculine
severe	.________.	.________.	.________.	.________.	.________.	lenient
weak	.________.	.________.	.________.	.________.	.________.	strong
tenacious	.________.	.________.	.________.	.________.	.________.	yielding
active	.________.	.________.	.________.	.________.	.________.	passive
excitable	.________.	.________.	.________.	.________.	.________.	calm
cold	.________.	.________.	.________.	.________.	.________.	hot
complex	.________.	.________.	.________.	.________.	.________.	simple
easy	.________.	.________.	.________.	.________.	.________.	hard
slow	.________.	.________.	.________.	.________.	.________.	fast

TECHNOLOGY						
bad	.________.	.________.	.________.	.________.	.________.	good
like	.________.	.________.	.________.	.________.	.________.	hate
loathe	.________.	.________.	.________.	.________.	.________.	welcome
interesting	.________.	.________.	.________.	.________.	.________.	dull
pleasant	.________.	.________.	.________.	.________.	.________.	foul
optimistic	.________.	.________.	.________.	.________.	.________.	pessimistic
hard	.________.	.________.	.________.	.________.	.________.	soft
light	.________.	.________.	.________.	.________.	.________.	heavy
feminine	.________.	.________.	.________.	.________.	.________.	masculine
severe	.________.	.________.	.________.	.________.	.________.	lenient
weak	.________.	.________.	.________.	.________.	.________.	strong
tenacious	.________.	.________.	.________.	.________.	.________.	yielding
active	.________.	.________.	.________.	.________.	.________.	passive
excitable	.________.	.________.	.________.	.________.	.________.	calm
cold	.________.	.________.	.________.	.________.	.________.	hot
complex	.________.	.________.	.________.	.________.	.________.	simple
easy	.________.	.________.	.________.	.________.	.________.	hard
slow	.________.	.________.	.________.	.________.	.________.	fast

Part II
Semantic differential (cont.)

ENGINEERING						
bad	.________.	.________.	.________.	.________.	.________.	good
like	.________.	.________.	.________.	.________.	.________.	hate
loathe	.________.	.________.	.________.	.________.	.________.	welcome
interesting	.________.	.________.	.________.	.________.	.________.	dull
pleasant	.________.	.________.	.________.	.________.	.________.	foul
optimistic	.________.	.________.	.________.	.________.	.________.	pessimistic
hard	.________.	.________.	.________.	.________.	.________.	soft
light	.________.	.________.	.________.	.________.	.________.	heavy
feminine	.________.	.________.	.________.	.________.	.________.	masculine
severe	.________.	.________.	.________.	.________.	.________.	lenient
weak	.________.	.________.	.________.	.________.	.________.	strong
tenacious	.________.	.________.	.________.	.________.	.________.	yielding
active	.________.	.________.	.________.	.________.	.________.	passive
excitable	.________.	.________.	.________.	.________.	.________.	calm
cold	.________.	.________.	.________.	.________.	.________.	hot
complex	.________.	.________.	.________.	.________.	.________.	simple
easy	.________.	.________.	.________.	.________.	.________.	hard
slow	.________.	.________.	.________.	.________.	.________.	fast

MATHEMATICS						
bad	.________.	.________.	.________.	.________.	.________.	good
like	.________.	.________.	.________.	.________.	.________.	hate
loathe	.________.	.________.	.________.	.________.	.________.	welcome
interesting	.________.	.________.	.________.	.________.	.________.	dull
pleasant	.________.	.________.	.________.	.________.	.________.	foul
optimistic	.________.	.________.	.________.	.________.	.________.	pessimistic
hard	.________.	.________.	.________.	.________.	.________.	soft
light	.________.	.________.	.________.	.________.	.________.	heavy
feminine	.________.	.________.	.________.	.________.	.________.	masculine
severe	.________.	.________.	.________.	.________.	.________.	lenient
weak	.________.	.________.	.________.	.________.	.________.	strong
tenacious	.________.	.________.	.________.	.________.	.________.	yielding
active	.________.	.________.	.________.	.________.	.________.	passive
excitable	.________.	.________.	.________.	.________.	.________.	calm
cold	.________.	.________.	.________.	.________.	.________.	hot
complex	.________.	.________.	.________.	.________.	.________.	simple
easy	.________.	.________.	.________.	.________.	.________.	hard
slow	.________.	.________.	.________.	.________.	.________.	fast

Before moving on to **Part III**, please read the directions below:

In this final part of the packet you will find a series of blocks like the one below:

Question A	Most ---------------- More ---------------- Less ---------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Each block contains a single statement. In this case, the statement is “I like:” as you can see above. To the right of the statement are four columns, each containing the acronym of S.T.E.M. listed vertically. S.T.E.M. refers to each of the four subjects we are measuring in this packet: ***science, technology, engineering,*** and ***mathematics***.

Above the four columns is a scale, ranging from Most to Least (shown below in detail)

Question A	Most ---------------- More ---------------- Less ---------------- Least

This scale assigns a level of intensity to each of the columns provided. Let’s look at an example to see how one of these blocks work.

Question A	Most ---------------- More ---------------- Less ---------------- Least			
I like:	S **X**	S	S	S
	T	T **X**	T	T
	E	E	E **X**	E
	M	M	M	M **X**

The student that filled out this question block is indicating the following:

I like science a lot (most)
I like technology (more)
I don’t like engineering (less)
I don’t like mathematics a lot (least)

Let’s examine a few more to be sure you understand this new concept.

Please continue on to the next page.

Question A	Most --------------- More --------------- Less --------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

The student that filled out this block is indicating the following:

I like science (more)
I like technology (more)
I like engineering a lot (most)
I like mathematics (more)

Question A	Most --------------- More --------------- Less --------------- Least			
I like:	S	S	S	[redacted]
	T	[redacted]	T	T
	E	E	[redacted]	E
	M	M	[redacted]	M

The student that filled out this block is indicating the following:

I do not like science a lot (least)
I like technology (more)
I do not like engineering (less)
I do not like mathematics (less)

Each of the blocks above indicates how a student may react to the four different subjects of S.T.E.M. The scale (most – least) allows the student to select a level of intensity for each subject reaction. In the examples, we see that subjects can both share and differ with their assigned level of intensity, depending on what the student decides. It is vital that the student look upon *each subject independently* with the provided statement (i.e., I like Science) and *not at the whole* (i.e., I like science, technology, engineering, and mathematics).

IMPORTANT:

1- **Clearly mark only ONE SUBJECT per row.**
2- **Place a mark for each of the four subjects (STEM), do not omit any. (i.e., there should always be 4 subjects marked per completed block)**
3- **Look at each question and subject independently, do not go back and forth through the subjects/questions.**
4- **Work quickly, your first and natural impression is what we are trying to measure. Do not try to 'over think' each scale or question.**

Part III begins on the following page.

Question 1	Most	--------------- More	--------------- Less	--------------- Least
I like to read about:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 2	Most	--------------- More	--------------- Less	--------------- Least
My school offers courses in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 3	Most	--------------- More	--------------- Less	--------------- Least
My school does not offer after-school programs in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 4	Most	--------------- More	--------------- Less	--------------- Least
I enjoy watching TV shows involving:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 5	Most	--------------- More	--------------- Less	--------------- Least
I do not want to learn more about:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 6	Most --------------- More --------------- Less --------------- Least			
I do not enjoy taking courses in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 7	Most --------------- More --------------- Less --------------- Least			
Courses in [subject] are available to me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 8	Most --------------- More --------------- Less --------------- Least			
I dislike the challenge of:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 9	Most --------------- More --------------- Less --------------- Least			
I am good at projects involving:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 10	Most --------------- More --------------- Less --------------- Least			
[subject] is difficult for me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 11	Most --------------- More --------------- Less --------------- Least			
I perform well in [subject] courses:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 12	Most --------------- More --------------- Less --------------- Least			
I can not handle advanced courses in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 13	Most --------------- More --------------- Less --------------- Least			
[subject] is simple:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 14	Most --------------- More --------------- Less --------------- Least			
I do not worry about taking tests in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 15	Most --------------- More --------------- Less --------------- Least			
I struggle in [subject] courses:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 16	Most --------------- More --------------- Less --------------- Least			
I do not understand:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 17	Most --------------- More --------------- Less --------------- Least			
Homework in [subject] is easy:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 18	Most --------------- More --------------- Less --------------- Least			
[subject] is important:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 19	Most --------------- More --------------- Less --------------- Least			
What I learn in [subject] has no value to me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 20	Most --------------- More --------------- Less --------------- Least			
I believe there is a need for:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 21	Most --------------- More --------------- Less --------------- Least			
I need:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 22	Most --------------- More --------------- Less --------------- Least			
Learning [subject] will not help me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 23	Most --------------- More --------------- Less --------------- Least			
[subject] is good:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 24	Most --------------- More --------------- Less --------------- Least			
I care about developments in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 25	Most --------------- More --------------- Less --------------- Least			
[subject] is not worth my time to understand:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 26	Most ---------------- More ---------------- Less ---------------- Least			
I would dislike more/advanced courses in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 27	Most ---------------- More ---------------- Less ---------------- Least			
I would like to participate in more after-school programs in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 28	Most ---------------- More ---------------- Less ---------------- Least			
I am curious about a career involving:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 29	Most ---------------- More ---------------- Less ---------------- Least			
I am interested in advanced programs involving:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 30	Most ---------------- More ---------------- Less ---------------- Least			
I have no interest in discovering new ways to apply:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 31	Most --------------- More --------------- Less --------------- Least			
[subject] is not a vital part of my perceived future:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 32	Most --------------- More --------------- Less --------------- Least			
I intend to further develop my abilities in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 33	Most --------------- More --------------- Less --------------- Least			
I will continue to enjoy the challenge of:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 34	Most --------------- More --------------- Less --------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

STOP

Please place this document along with the required materials
in the provided envelop and bring back to school to be collected by the researcher.
If the packet is late or missing documents, you will not be entered into the raffle.

THANK YOU

APPENDIX C: INSTRUMENT COVER PAGE: REVISED

WE NEED YOUR HELP!

The Ohio State University and your high school are trying to measure high school students' attitudes toward the subjects of science, technology, engineering and mathematics (STEM). We want your input! You are the focus and function of high schools, and your thoughts about these STEM subjects are as vital as the classes themselves. The information that you provide on this survey will aide in the development of a measurement device that will allow schools like yours to improve their programs to better meet the needs of students as well as local and national educational requirements.

Your responses on this survey will remain confidential. *NO ONE* in your school (teachers, administrators, or students) will see your responses on this survey. Participation in this study will have *NO EFFECT* on your academic standing or grades.

If you choose to participate, you will be entered into a raffle for a chance to win a…

$100 worth of Gift Cards to stores of your choosing*

(*Actual card will vary depending on availability)

To be entered into the raffle, you must complete all the paper work included in the packet provided to you. The items that must be returned are listed below:

- **Student permission form – Signed by you**
- **Parent permission form – Signed by your parent(s)/legal guardian(s)**
- **Student Attitude Survey – Correctly filled out**

If you return the packet and any of the above documents are either not correctly filled out or are missing completely, you will not be entered into the raffle. All documents are due on the date and time provided by the researcher when the packets were distributed.

NOTE: A small collection of students who complete the packet correctly may be contacted to participate in a small focus group. The purpose of this focus group is to make sure the survey and its questions were clear and easy to understand. Your actual responses on the survey will remain confidential and are not a part of this focus group activity. Your participation in this focus group if contacted is VOLUNTARY and will have no influence upon your chances in the raffle or your standing in the school.

APPENDIX D: STUDENT ATTITUDE TOWARD STEM INSTRUMENT: REVISED

Student attitude toward STEM
Initial Instrument Review

In cooperation with
THE OHIO STATE UNIVERSITY

Researchers:
Karen Zuga, Principal Investigator
Mark Mahoney, Co-investigator

IRB Protocol number: 2008B0295
IRB Protocol approval date: 1/18/2009
IRB Protocol revision approval date: 4/13/09

The following definitions are to clarify what is implied by each of the STEM subjects; science, technology, engineering, and mathematics. Please review these definitions provided before proceeding on to the survey.

Science:

The systematic observation of natural events in order to obtain facts about them and to formulate laws and principles based on these facts. Science is the organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation. There are several sections of the general body of knowledge relating to science; such as biology, physics, chemistry, geology, or astronomy.
(Academic Press Dictionary of Science & Technology)

Technology:

Technology is the process by which humans modify nature to meet their needs and wants. Most people, however, think of technology in terms of its artifacts: computers and software, aircraft, pesticides, water-treatment plants, birth-control pills, and microwave ovens, to name a few. But technology is more than these tangible products. Technology includes the entire infrastructure necessary for the design, manufacture, operation, and repair of technological artifacts, from corporate headquarters and engineering schools to manufacturing plants and maintenance facilities. The knowledge and processes used to create and to operate technological artifacts -- engineering know-how, manufacturing expertise, and various technical skills -- are equally important part of technology.
(National Academy of Engineering)

Engineering:

The profession of or work performed by an engineer. Engineers are problem solvers who search for quicker, better, and less expensive ways to use the forces and materials of nature to meet today's challenges. Engineering involves the knowledge of the mathematical and natural sciences (biological and physical) gained by study, experience, and practice that are applied with judgment and creativity to develop ways to utilize the materials and forces of nature for the benefit of mankind.
(American Society for Engineering Education)

Mathematics:

Study of abstract patterns and relationships that results in an exact language used to communicate about them. Mathematics is also considered science of structure, order, and relation that has evolved from elemental practices of counting, measuring, and describing the shapes of objects. It deals with logical reasoning and quantitative calculation, and its development has involved an increasing degree of idealization and abstraction of its subject matter.
(Webster-Merriam, Encyclopedia Britannica)

PART I
Demographic information
Please place a **check-mark** or an **X** in the column that best corresponds with the question or statement provided:

Current Grade Level:	9th	10th	11th	12th

Current Age: (in years)	13	14	15	16	17	18

Gender:	Male	Female

Current Grade Level:	9th	10th	11th	12th

Ethnicity:	Black	White	Asian	Hispanic
If other, please specify:				

G.P.A: (Grade point average)	<1.0	1.0 – 1.9	2.0 – 2.9	3.0 – 3.4	3.5 – 4.0

Does you school offer classes/courses in:	YES	If yes, how many?	NO
Science			
Technology			
Engineering			
Mathematics			

Please continue on to the next page.

PART I
Demographic information (continued)

Does your school offer after-school, weekend, or summer programs in:	YES	If yes, how many?	NO
Science			
Technology			
Engineering			
Mathematics			

How many classes/courses have you taken in:	0	1	2	3	4	5+
Science						
Technology						
Engineering						
Mathematics						

How many after-school, weekend, or summer programs have you participated with involving:	0	1	2	3	4	5+
Science						
Technology						
Engineering						
Mathematics						

What do you think you want to do for a career:	

This completes PART I

Please continue on to the next page.

Before moving on to **PART II**, please read the directions below:

In this part of the packet you will find a series of blocks like the one below:

Question A	Most ---------------- More ---------------- Less ---------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Each block contains a single statement. In this case, the statement is “I like:” as you can see above. To the right of the statement are four columns, each containing the acronym of S.T.E.M. listed vertically. S.T.E.M. refers to each of the four subjects we are measuring in this packet: ***science, technology, engineering,*** and ***mathematics***.

Above the four columns is a scale, ranging from Most to Least (shown below in detail)

Question A	Most ---------------- More ---------------- Less ---------------- Least

This scale assigns a level of intensity to each of the columns provided. Let’s look at an example to see how one of these blocks work.

Question A	Most ---------------- More ---------------- Less ---------------- Least			
I like:	S X	S	S	S
	T	T X	T	T
	E	E	E X	E
	M	M	M	M X

The student that filled out this question block is indicating the following:

I like science a lot (most)
I like technology (more)
I don’t like engineering (less)
I don’t like mathematics a lot (least)

Let’s examine a few more to be sure you understand this new concept.

Please continue on to the next page.

Question A	Most ---------------- More ---------------- Less ---------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

The student that filled out this block is indicating the following:

I like science (more)
I like technology (more)
I like engineering a lot (most)
I like mathematics (more)

Question A	Most ---------------- More ---------------- Less ---------------- Least			
I like:	S	S	S	[redacted]
	T	[redacted]	T	T
	E	E	[redacted]	E
	M	M	[redacted]	M

The student that filled out this block is indicating the following:

I do not like science a lot (least)
I like technology (more)
I do not like engineering (less)
I do not like mathematics (less)

Each of the blocks above indicates how a student may react to the four different subjects of S.T.E.M. The scale (most – least) allows the student to select a level of intensity for each subject reaction. In the examples, we see that subjects can both share and differ with their assigned level of intensity, depending on what the student decides. It is vital that the student look upon *each subject independently* with the provided statement (i.e., I like Science) and *not at the whole* (i.e., I like science, technology, engineering, and mathematics).

IMPORTANT:

1- **Clearly mark only ONE SUBJECT per row.**
2- **Place a mark for each of the four subjects (STEM), do not omit any. (i.e., there should always be 4 subjects marked per completed block)**
3- **Look at each question and subject independently, do not go back and forth through the subjects/questions.**
4- **Work quickly, your first and natural impression is what we are trying to measure. Do not try to 'over think' each scale or question.**

PART II begins on the following page.

Question 1	Most ---------------- More ---------------- Less ---------------- Least			
I do **not** like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 2	Most ---------------- More ---------------- Less ---------------- Least			
I enjoy learning about:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 3	Most ---------------- More ---------------- Less ---------------- Least			
I am curious about:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 4	Most ---------------- More ---------------- Less ---------------- Least			
I am **not** interested in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 5	Most ---------------- More ---------------- Less ---------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 6	Most --------------- More --------------- Less --------------- Least			
(subject) is appealing to me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 7	Most --------------- More --------------- Less --------------- Least			
(subject) is **difficult** for me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 8	Most --------------- More --------------- Less --------------- Least			
I do well in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 9	Most --------------- More --------------- Less --------------- Least			
I am **not** confident about my work in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 10	Most --------------- More --------------- Less --------------- Least			
I have a **hard-time** in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 11	Most --------------- More --------------- Less --------------- Least			
Assigned work in (subject) is easy for me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 12	Most --------------- More --------------- Less --------------- Least			
I can **not** figure out:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 13	Most --------------- More --------------- Less --------------- Least			
(subject) is important to me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 14	Most --------------- More --------------- Less --------------- Least			
I feel there is a need for:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 15	Most --------------- More --------------- Less --------------- Least			
I do **not** need:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 16	Most --------------- More --------------- Less --------------- Least			
It is valuable for me to learn:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 17	Most --------------- More --------------- Less --------------- Least			
(subject) is good for me:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 18	Most --------------- More --------------- Less --------------- Least			
I do **not** care about:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 19	Most --------------- More --------------- Less --------------- Least			
I will continue to enjoy:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 20	Most --------------- More --------------- Less --------------- Least			
I am **not** interested in a career involving:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Please continue on to the next page.

Question 21	Most ---------------- More ---------------- Less ---------------- Least			
I am interested in alternative programs in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 22	Most ---------------- More ---------------- Less ---------------- Least			
I would like to learn more about:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 23	Most ---------------- More ---------------- Less ---------------- Least			
I do **not** wish to continue my education in:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Question 24	Most ---------------- More ---------------- Less ---------------- Least			
I am committed to learning:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

STOP

Please place this document along with the required materials
in the provided envelop, seal the envelop, and bring the materials
back to school to be collected by the researcher.
If the packet is late or missing portions, you will not be entered into the raffle.

THANK YOU

APPENDIX E: STUDENT ASSENT FORM

The Ohio State University Assent to Participate in Research

Study Title:	**Student attitude toward STEM: Development of an instrument for high school STEM-based programs.**
Researchers:	Dr. Karen Zuga (principal investigator) Mark Patrick Mahoney (co-investigator)
Sponsor:	

- **You are being asked to be in a research study. Studies are done to find better ways to treat people or to understand things better.**
- **This form will tell you about the study to help you decide whether or not you want to participate.**
- **You should ask any questions you have before making up your mind. You can think about it and discuss it with your family or friends before you decide.**
- **It is okay to say "No" if you don't want to be in the study. If you say "Yes" you can change your mind and quit being in the study at any time without getting in trouble.**
- **If you decide you want to be in the study, an adult (usually a parent) will also need to give permission for you to be in the study.**

1. **What is this study about?**
   This study is about high schools student attitude toward science, technology, engineering, and mathematics, more commonly referred to as STEM.

2. **What will I need to do if I am in this study?**
   As a participant in the study, you must first obtain permission from your parents (form inside packet). Once they have given you permission, you also must agree to take part in the study (this form). Finally, you simply follow the directions provided on the survey located inside the packet, and answer as honestly as you can to the questions provided. Later on, you may be picked to be interviewed regarding your experience with the study. This will be done at your school with some of your other classmates as well.

3. **How long will I be in the study?**
   You are in the study for as long as it takes you to fill out the survey and return it to the researcher. If you are selected for the interview, you will be asked to answer some questions regarding your experience taking the survey. The group interview will not last more than thirty minutes.
4. **Can I stop being in the study?**
   You may stop being in the study at any time.

5. What bad things might happen to me if I am in the study?
Nothing will happen to you for being in this study.

6. What good things might happen to me if I am in the study?
Nothing will happen to you for being in this study.

7. Will I be given anything for being in this study?
If you complete the whole study as directed and return all the documents to the researcher correctly filled out, then you will be entered into raffle and have a chance to win a total of $100 worth of Gift Cards to stores of their choosing. Choosing to participate or not participate in the interview process will have no affect on your raffle chances.

8. Who can I talk to about the study?
For questions about the study you may contact either Dr. Karen Zuga at (614)292-7471 or Mark Mahoney at (860)944-2505.

To discuss other study-related questions with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

Signing the assent form

I have read (or someone has read to me) this form. I have had a chance to ask questions before making up my mind. I want to be in this research study.

____________________________________ ____________________________ **AM/PM**
Signature or printed name of subject **Date and time**

<u>Investigator/Research Staff</u>

I have explained the research to the participant before requesting the signature above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

____________________________________ ____________________________
Printed name of person obtaining assent **Signature of person obtaining assent**

____________________________ **AM/PM**
Date and time

This form must be accompanied by an IRB approved parental permission form signed by a parent/guardian.

APPENDIX F: PARENT PERMISSION FORM

The Ohio State University Parental Permission For Child's Participation in Research

Study Title:	**Student attitude toward STEM: Development of an instrument for high school STEM-based programs.**
Researcher:	Dr. Karen Zuga (principal investigator) Mark Patrick Mahoney (co-investigator)
Sponsor:	

This is a parental permission form for research participation. It contains important information about this study and what to expect if you permit your child to participate.

Your child's participation is voluntary.

Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to permit your child to participate. If you permit your child to participate, you will be asked to sign this form and return it to the researcher. If you would like a copy, please contact the researcher so that one may be provided to you.

Purpose:

To develop an instrument that measures the level of student attitude toward science, technology, mathematics, and engineering (STEM).

Procedures/Tasks:

Once you and your child have given consent, the child must complete the enclosed attitude instrument. Upon completion, simply place all signed documents and instrument in the provided envelope and return to the researcher on the agreed upon date. Later on, your child may be picked to be interviewed regarding their experience with the study. This will be done at the high school with some of the other student who experienced the research. None of the information from the packets will be shared. This interview is simply performed to establish student understanding of the instrument as well as question clarity.

Duration:

Your child will be in the study for as long as it takes them to fill out the survey and return it to the researcher. If they are selected for the interview, they will be asked to answer some questions regarding their experience taking the survey. The interview will not last more than thirty minutes and will be performed during the school day. Your child may leave the study at any time. If you or your child decides to stop participation in the study, there will be no penalty and neither you nor your child will lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

Risks and Benefits:
The information provided this instrument will provide the following:

- Allow for early STEM program revisions (as needed)
- Aid in the determination of appropriate STEM program funding
- Assist schools in selecting STEM programs for implementation
- Determine the value of educational investments (if applicable) from major organizations and industries
- Depict the possible future market for STEM students/employees

Confidentiality:

Efforts will be made to keep your child's study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your child's participation in this study may be disclosed if required by state law. Also, your child's records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Incentives:
Students that return a completed packet, which includes the appropriately filled-out instrument, parent permission form and student ascent form, will have their names placed in a raffle. This will occur for each school involved in the study. The winning student from each school will receive a $100 worth of gift cards (toward stores of their choosing) for their involvement.

Participant Rights:

You or your child may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you or your child is a student or employee at Ohio State, your decision will not affect your grades or employment status.

If you and your child choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights your child may have as a participant in this study.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

Contacts and Questions:

For questions, concerns, or complaints about the study you may contact either **Dr. Karen Zuga** at **(614)292-7471** or **Mark Mahoney** at **(860)944-2505**.

For questions about your child's rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

Signing the parental permission form

I have read (or someone has read to me) this form and I am aware that I am being asked to provide permission for my child to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to permit my child to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form**.**

____
Printed name of subject

Printed name of person authorized to provide permission for subject	**Signature of person authorized to provide permission for subject**
Relationship to the subject	**Date and time** AM/PM

<u>Investigator/Research Staff</u>

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

Printed name of person obtaining consent	**Signature of person obtaining consent**
	AM/PM

APPENDIX G: INSTRUMENT ITEMS LIST COMPARISON

Student attitude toward STEM: Instrument items development

Category	Initial items:	Revised items:
Awareness:	1. I like to read about: 2. My school offers courses in: 3. My school does not offer after school programs in: 4. I enjoy watching TV shows involving: 5. I do not want to learn more about: 6. I do not enjoy taking courses in: 7. Courses in [subject] are available to me 8. I dislike the challenge of: 34. I like:	1. I do not like 2. I enjoy learning about 3. I am curious about 4. I am not interested in 5. I like 6. (subject) is appealing to me
Ability:	9. I am good at projects involving: 10. [subject] is difficult for me: 11. I perform well in [subject] courses: 12. I can not handle advanced courses in: 13. [subject] is simple: 14. I do not worry about taking tests in: 15. I struggle in [subject] courses: 16. I do not understand: 17. Homework in [subject] is easy:	7. (subject) is difficult for me 8. I do well in 9. I am not confident about my work in 10. I have a hard time in 11. Assigned work in (subject) is easy for me 12. I can not figure out
Value:	18. [subject] is important 19. What I learn in [subject] has no value to me: 20. I believe there is a need for: 21. I need: 22. Learning [subject] will not help me: 23. [subject] is good: 24. I care about developments in: 25. [subject] is not worth my time to understand:	13. (subject) is important to me 14. I feel there is a need for 15. I do not need 16. It is valuable for me to learn 17. (subject) is good for me 18. I do not care about
Commitment:	26. I would dislike more/advanced courses in: 27. I would like to participate in more after-school programs in: 28. I am curious about a career involving: 29. I am interested in advanced programs involving: 30. I have no interest in discovering new ways to apply: 31. [subject] is not a vital part of my perceived future: 32. I intend to further develop my abilities in: 33. I will continue to enjoy the challenge of:	19. I will continue to enjoy 20. I am not interested in a career involving 21. I am interested in alternative programs in 22. I would like to learn more about 23. I do not wish to continue my education in 24. I am committed to learning

(continued)

Student attitude toward STEM: Instrument items development (continued)

The revised items were developed from a collective effort involving principal components analysis, student focus group, panel of experts, and researcher review. The following is a brief description of each items revision:

1. *I do not like* – created as a negative variation of the original instrument "I like" item. Also, this item was implemented as a revision of the previous item "I like to read about." The previous item was revised because of the overly specific assumption indicated by the term "read."
2. *I enjoy learning about* – created as an alternative to "I enjoy watching TV," "I do not want to learn more about," and "I do not enjoy taking courses in" items from the original instrument due to low or inconsistent scores and student interpretations. The item intends to allow for a more general student interpretation when compared to the original items from which it was created.
3. *I am curious about* – created as an alternative to "My school offers course in" and "Courses in [subject] are available to me." The intent of this item is to address the possible lack of exposure to STEM as indicated by student interviews and still indicate a level of interest.
4. *I am not interested in* – created as less "severe" interpretation of "I do not like." This item is a general item for the overall interest category. Previous items were deemed to be too specific, therefore, an elementary approach was deemed appropriate.
5. *I like* – carried over from previous instrument without revision.
6. *(subject) is appealing to me* – created as an alternative to "enjoy" used in other instrument items (initial and revised). "Enjoy" may present additional attitudinal constructs other than interest for which it was intended.
7. *(subject) is difficult for* me – carried over form original instrument.
8. *I do well in* – modification of "I perform well in [subject] courses." This was done to allow the item to appeal to a broader student interpretation. "Perform" was indicated as dealing directly with an action; actions are not always associated with all STEM content areas. "Do" proposes a "flexible" interpretation – as indicated by students –

that should allow the reader to mold the item to fit their own experience with the content area.

9. *I am not confident about my work in* – created as a general and negative modification from the "Homework in [subject] is easy" item. Homework was deemed to be too specific for all content areas of STEM. Work is a general enough term that it may be applied to homework, assignments, projects, etc.
10. *I have a hard time in* – created as a general interpretation from the initial instrument item "[subject] is difficult for me." Again, words were chosen to be more applicable to high school student language as indicated by student suggestions
11. *Assigned work in (subject) is easy for me* – a second modification of the "Homework in [subject] is easy] item; specifically to address assignments rather than "day to day" operations experienced by students – which could be deemed as work (see revised item 9).
12. *I can not figure out* – modification of "I do not understand" item from previous instrument. "Figure out" was chosen to be more applicable to high school student language as indicated by student suggestions rather than "understand."
13. *(subject) is important to me* – carried over from previous instrument with greater emphasis on the self. The directed focus on the individual person may increase the likelihood of an accurate value measurement.
14. *I feel there is a need for* – generalization of the "I believe there is need for" item previously used. 'Believe' was considered to be too specific to construct other than attitude and/or value and therefore was replaced with 'feel.'
15. *I do not need* – negative inflection of the previous instrument item "I need."
16. *It is valuable for me to learn* – variation of previous instrument item "Learning [subject] will not help me." This item intends to be more general for student interpretation. The intent was greater focus on the intended aspect of worth/value rather than aid/assistance.
17. *(subject) is good for me* – carried over from previous instrument with greater emphasis on the self. The directed focus on the individual person may increase the likelihood of an accurate value measurement.

18. *I do not care about* – modification of previous instrument item "I care about developments in." The original item contained elements of long-term interest (commitment) though the apparent use of the word 'developments' appeared to skew the intended focus of measurement.
19. *I will continue to enjoy* – carried over form pervious instrument with greater concentration upon interest. Removal of the word 'challenge' was made due to conflicting interpretations regarding student perceived ability.
20. *I am not interested in a career involving* – modified from previous instrument item "I am curious about a career involving" due to inconsistent interpretation.
21. *I am interested in alternative programs in* – created in an attempt to address possible student interest in after-school programs and/or advanced programs previously sought in the original instrument items "I would dislike more/advance courses in" and "I would like to participate in more after-school programs in."
22. *I would like to learn more about* – modification of the items "I would dislike more/advanced course in" and "I have no interest in discovering new ways to apply" due to negative implications derived by the phrases 'more/advanced courses' and "new ways to apply" as indicated through student interviews.
23. *I do not wish to continue my education in* – created to measure future intentions indicated by students; as implicated by previous items "I intend to further develop my abilities in," "I have no interest in discovering new ways to apply," "I would dislike more/advanced courses in," and "I am interested in advanced programs involving."
24. *I am committed to learning* – created as a general indicator of long-term interest. This item was developed as an alternative to item #23 to correct for the same initial instrument items.

APPENDIX H: PEARSON PRODUCT MOMENT CORRELATION:
STUDENT ATTITUDE TOWARD STEM INSTRUMENT
AND THE SEMANTIC DIFFERENTIAL

Student attitude toward STEM and semantic differential correlation

Pearson product moment correlation			
		Student attitude toward STEM items 136 items	SEMDIFF bi-polar pairs 72 items
SEMDIFF bi-polar pairs 72 items	Pearson Correlation	.55**	
	Sig. (2-tailed)	.001	
	N	31	
SEMDIFF bi-polar pairs (modified) 44 items	Pearson Correlation	.63**	.98**
	Sig. (2-tailed)	.000	.000
	N	31	31
		Science student attitude toward STEM items 34 items	Science SEMDIFF bi-polar pairs 18 items
Science SEMDIFF bi-polar pairs 18 items	Pearson Correlation	.46*	
	Sig. (2-tailed)	.013	
	N	31	
Science SEMDIFF bi-polar pairs (modified) 11 items	Pearson Correlation	.48**	.98**
	Sig. (2-tailed)	.010	.000
	N	31	31
		Technology student attitude toward STEM items 34 items	Technology SEMDIFF bi-polar pairs 18 items
Technology SEMDIFF bi-polar pairs 18 items	Pearson Correlation	.41*	
	Sig. (2-tailed)	.031	
	N	31	31
Technology SEMDIFF bi-polar pairs (modified) 11 items	Pearson Correlation	.40*	.98**
	Sig. (2-tailed)	.034	.000
	N	31	31

(continued)

Student attitude toward STEM and semantic differential correlation (continued)

		Engineering student attitude toward STEM items 34 items	Engineering SEMDIFF bi-polar pairs 18 items
Engineering SEMDIFF bi-polar pairs 18 items	Pearson Correlation	.50**	
	Sig. (2-tailed)	.007	
	N	31	31
Engineering SEMDIFF bi-polar pairs (modified) 11 items	Pearson Correlation	.63**	.92**
	Sig. (2-tailed)	.000	.000
	N	31	31
		Mathematics student attitude toward STEM items 34 items	Mathematics SEMDIFF bi-polar pairs 18 items
Mathematics SEMDIFF bi-polar pairs 18 items	Pearson Correlation	.75**	
	Sig. (2-tailed)	.000	
	N	31	
Mathematics SEMDIFF bi-polar pairs (modified) 11 items	Pearson Correlation	.76**	.98**
	Sig. (2-tailed)	.000	.000
	N	31	31

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)