IJEMST

International Journal of Education in Mathematics, Science and Technology

ISSN: 2147-611X

International Journal of Education in Mathematics, Science and Technology (IJEMST)

www.ijemst.com

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To cite this article:

Alemdar, M., Moore, R.A., Lingle, J. A., Rosen, J, Gale, J., & Usselman, M. C. (2018). The impact of a middle school engineering course on students' academic achievement and non-cognitive skills. *International Journal of Education in Mathematics, Science and Technology (IJEMST), 6*(4), 363-380. DOI: 10.18404/ijemst.440339

IJEMST
International Journal of Education in Mathematics, Science and Technology
Volume 6, Number 4, 2018 DOI:10.18404/ijemst.440339

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Article Info

Article History

Received:
14 July 2017

Accepted:
19 November 2017

Keywords

K-12 engineering education
STEM integration
Longitudinal study
Science and mathematics achievement

Abstract

Engineering and integrated STEM experiences are being promoted at the K-12 level to increase interest and retention in STEM and to reinforce learning of mathematics and science content. However, research is still emerging regarding best practices for curriculum development, student impacts, and transfer of knowledge across disciplines. The purpose of this study is to investigate the impact of middle school engineering curriculum on students' academic achievement in science and mathematics and also on non-cognitive skills such as student engagement and self-efficacy in academics. Specifically, the Engineering Design Process (EDP) conceptual model is used as a framework for the engineering curriculum, which is also grounded in Problem-Based Learning (PBL) practices while integrating science practices and foundational mathematics. Participants include 6^{th}-8^{th} grade students at four public middle schools in Georgia. The research results show that students who have taken at least two engineering courses show statistically significant gains on state-level standardized science and mathematics tests over those students who were never enrolled in these courses. Further, the results show a statistically significant increase in cognitive and behavioral engagement in STEM and science interest. The results of this study support the idea that enabling students to practice their science and mathematics skills and knowledge within the context of interesting and engaging middle school engineering classes can significantly benefit both their engagement in STEM and their academic achievement.

Introduction

In 2012, the National Academies of Science and Engineering released *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2012). Based on research about teaching and learning conducted over the previous 20 years, the *Framework* detailed the content and practices most central to conducting science and therefore most essential for students to learn. It also, for the first time, included engineering as an important element in science education. Engineering, defined as "any engagement in a systematic practice of design to achieve solutions to particular human problems" (p. 11), provides particularly compelling contexts within which to learn science. The framework also contended that practicing engineering design is an important facet of science education. Recognizing that few instructional materials available at that time supported the tenets of the Framework and subsequent Next Generation Science Standards (NGSS; NGSS Lead States, 2013), the National Academies challenged curriculum designers, educators, and researchers to create multiyear sequences of instructional materials that align with this new vision of integrated education, and to provide the support for teachers needed for effective implementation.

The Advanced Manufacturing and Prototyping Integrated to Unlock Potential (AMP-IT-UP) project, funded in 2012 by the National Science Foundation through the Math and Science Partnership program, took up the challenge to integrate science, engineering, and mathematics. Focusing on the middle school grade band, which has been shown to be a particularly crucial period for getting students engaged in mathematics and science and for increasing student interest in engineering as a profession (Tafoya, Nguyen, Skokan, & Moskal, 2005), AMP-IT-UP developed, implemented, and assessed a three-year middle school engineering and technology course sequence that aligns with the Framework and NGSS and adopts a pedagogical structure of inquiry and problem-based learning (PBL). This paper describes a three-year longitudinal study of middle school students enrolled in this engineering course sequence, and the effects on student outcomes.

The engineering courses are designed based on a hypothesis that applied engineering experiences that require active engagement with foundational mathematics and science practices will lead to increased student engagement, self-efficacy, persistence, and academic achievement in STEM. This hypothesis is based on the published literature (Kolodner et al., 2003; Cantrell, Pekcan, Itan, & Velasquez-Bryant, 2006; Mehalik, Doppelt, & Schuun, 2008) as well as years of experience by the curriculum developers of teaching students who struggle to find relevance in their education. The design team also proposed that the engineering curriculum be grounded in a PBL model of instruction, a format well suited to semester-long elective courses that have few disciplinary standards that must be met. The three engineering courses developed for 6th, 7th, and 8th grades provide students with what is, in effect, a *5th core subject*, focused on engineering. The courses integrate science and mathematics with engineering design, enabling students to explore and practice engineering, mathematics, and science skills in a low-risk, non-high-stakes-tested environment. By emphasizing foundational mathematics and science skills that students have been exposed to in earlier grades, rather than new grade-level-specific disciplinary content, curriculum designers explicitly sought to minimize the types of cognitive overload that can be a hazard of STEM integration and interdisciplinary content (National Research Council, 2014; Spelt et al., 2009). The engineering design challenges were conceived as vehicles through which students could strengthen and deepen their general STEM foundation, rather than as opportunities to introduce new disciplinary content for students to draw connections between and concurrently attempt to master.

The engineering course sequence was designed, implemented, tested, and redesigned within a low-income, rural fringe school system in Georgia, reflecting the view that curricula targeted for lower-performing and challenging school settings is best designed from the beginning within that type of setting (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013). A growing number of researchers are seeking to understand whether developing engineering "habits of mind and action" (National Research Council, 2012) in middle school leads to improvements in problem-solving abilities, integration of STEM content, and increased interest in engineering. Research also focuses on how to foster students' understanding of engineering fields, and how engineering utilizes mathematics and science (Dawes & Rassmussen, 2007). The purpose of this study is to investigate the impact of a multiyear middle school engineering curriculum on students' achievement in science and mathematics knowledge and non-cognitive skills such as student engagement and self-efficacy in academics to address the following research questions:

- What is the effect of participation in the multi-year engineering courses on student performance related to engineering design, science, and mathematics?
- What is the effect of participation in the multi-year engineering courses on students' engagement and self-efficacy in academics?

Theoretical Framework

The overall theoretical framework for the engineering course curriculum design is to utilize the Engineering Design Process (EDP) within a PBL context, combined with an emphasis on science and mathematics practices, as defined by the Next Generation Science Standards (NGSS Lead States, 2013) and the Standards of Mathematical Practice (SMP; Illustrative Mathematics, 2014.). The EDP is a conceptual model that describes the iterative process through which engineers address design challenges. A variety of EDP models have been created and implemented as guiding frameworks for engineering education; these models vary in terms of specific terminology and sequences (Carberry, Lee, & Ohland, 2010). Figure 1 shows the specific EDP model that guided the development of the multiyear engineering curriculum and related assessments that are the subject of this study. The model includes a starting point, *Defining the Problem*, and an ending point, *Communicating your Solution*, and emphasizes, with arrows, the iterative nature of the intermediate steps. The focus of the engineering course sequence in this study is not on students mastering specific step sequences or terminology, but rather on students understanding the process more holistically as a way to guide solution development.

PBL is a cognitive-apprenticeship approach with roots in medical school training (Barrows, 1985; Collins, Brown, & Newman, 1989), in which students work collaboratively to solve problems. Students identify what they know and what they need to learn, plan how they will learn more, conduct research, and deliberate over the findings together in an attempt to structure and solve a challenge or problem. Studies have found that PBL promotes more active learning of content, development of problem-solving skills, increased ownership in learning, more flexible thinking, improved collaboration skills, and opportunities for students to practice and gain expertise in STEM (Krajcik et al., 1998; Bransford, 1999; Hmelo-Silver & Pfeffer, 2004).

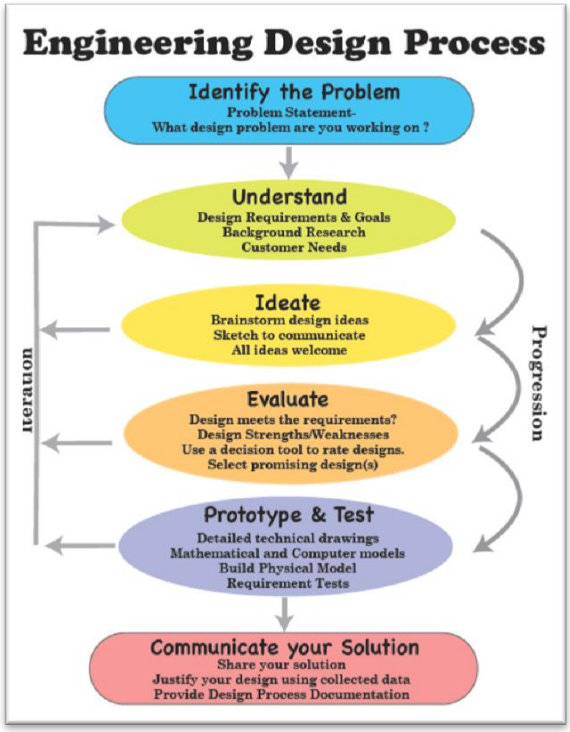

Figure 1. Engineering design process

The engineering courses in this study generally do not focus on grade-level-specific mathematics and science disciplinary content. Instead, students regularly practice foundational mathematics skills such as measuring, computing, estimating, graphing, and using mathematical reasoning in parallel with their grade-level mathematics and science courses. The course curriculum also emphasizes specific mathematics and science practices, grouped into three overarching themes that relate to the collection, visualization, interpretation, and communication of data. The three themes are: (1) *Experimental Design*, (2) *Data Visualization*, and (3) *Data-Driven Decision Making*.

The Experimental Design theme emphasizes concepts included in NGSS Practice #3: *Planning and Carrying Out Investigations*, Standards of Mathematical Practice (SMP) #1: *Make Sense of Problems* (e.g., plan a solution pathway), and SMP #5: *Use Appropriate Tools Strategically*. When engaging in these practices, students identify and control variables, create procedures, conduct experiments, use data-collection tools, and collect and analyze data. Students in the engineering classes are challenged to set up and run tests, identify variables that cause inconsistent results across groups, agree on standard procedures, re-run tests, and graph data to demonstrate that data converge as procedures become standardized.

The Data Visualization theme includes concepts from NGSS Practice #4: *Analyzing and Interpreting Data* (e.g., making and using graphical displays), SMP #1: *Make Sense of Problems* (e.g., graph data and search for regularity or trends) and SMP #4: *Model with Mathematics* (e.g., map relationships using diagrams, two-way tables, graphs). The emphasis of this theme is that data can be represented in multiple ways, that different types of visualizations enable people to extract different meaning from the evidence, and that the best data visualization is the representation that most effectively illustrates the concept that the user wants to communicate.

The third theme, Data-Driven Decision Making, asks students to make decisions or design solutions based on data in circumstances where there is not one simple solution and where trade-offs may exist. The engineering courses introduce decision matrices as a tool for organizing data to extract meaning and inform decisions, and students then communicate and defend their decisions. This theme incorporates NGSS Practice #6: *Constructing Explanations and Designing Solutions*, as well as NGSS Practice #7: *Engaging in Argument from Evidence*, and the communication component of NGSS Practice #8: *Obtaining, Evaluating and Communicating Information*. It also supports the mathematics standards of SMP #1: *Make Sense of Problems* (e.g., analyze givens, constraints, relationships, and goals), and SMP #3: *Construct viable arguments*.

Middle School Engineering Course Curriculum Description

The multiyear engineering course sequence consists of three 18-week courses. The courses are designed to satisfy the state-level engineering and technology course standards for 6th, 7th and 8th grade, but can also be implemented as STEM Connections courses. Individual courses are divided into a series of four challenges, the first three of which build different skills. The fourth challenge is a multi-week design challenge, which pulls the experience together. The challenges are titled the *Data Challenge*, *Systems Challenge*, *Visualization Challenge*, and *Design Challenge*. Table 1 lists the skills and practices used in each challenge, using the 6th grade course as an example. The skills fall into five different categories: Engineering & Problem Solving Skills, Cross-Disciplinary Skills, Science and Math Practices, Foundational Math, and Communication. The final Design Challenge requires that students demonstrate all of the skills developed in the previous challenges.

Table 1. 6th grade engineering course skills and practices: Carnival Tycoon

	Engineering and Problem-Solving Skills	**Cross-Disciplinary Skills**	**Science and Math Practices**	**Foundational Math**	**Communication**
Data Challenge	Decision-making using data	Data Collection & Analysis	Analyzing & Interpreting Data Engaging in Argument from Evidence	Fractions, Arithmetic, Calculating Profit	Sales Pitch
Systems Challenge	Engineering Design Process	Probability Validation	Analyzing & Interpreting Data	Probability, Profit	Presentation of a Design
Visualization Challenge	3D Drawing	Spatial Reasoning	Developing & Using Models	Geometry, Surface Area, Volume, Rotation	Using visuals and drawings to convey an idea
Design Challenge	All of the above	All of the above	All of the above	All of the above	All of the above

The 6th grade course is entitled “Carnival Tycoon” and contains carnival-themed challenges—a context with which most students are familiar. In the introductory Data Challenge, students create a sales pitch for a new carnival food stand, based on data collected through surveying their fellow students. They then conduct a profit analysis and pitch their anticipated earnings, requiring the use of fractions, multi-step problem solving, division, and mathematical reasoning.

In the Systems Challenge, students use a pneumatic catapult to design a new carnival game with certain odds of winning. This involves measuring, plotting points on the coordinate plane, developing experimental procedures, isolating variables, and calculating probabilities. During the Visualization Challenge, students sketch cube structures from different perspectives to develop spatial reasoning skills. They concurrently touch on engineering drawing conventions and geometric concepts such as surface area and volume. Finally, in the Design Challenge students re-design a catapult cradle to change the performance characteristics of their carnival game.

The 7th and 8th grade engineering courses follow a trajectory similar to that of the 6th grade course and incorporate many of the same skills, but within different contexts and with increasingly challenging technological manipulatives. For example, in the 7th grade aerospace-themed “Flight of Fancy” course, instead of creating hand drawings as they did in 6th grade, the students are introduced to CAD software (CAD 200, n.d.). They ultimately re-design an interior cabin and airplane wing geometry to make an airplane more fuel-efficient, comfortable, and profitable. The 8th grade “Biobots” course is grounded in robotics. Students design “feet” for a walking insect-bot, render them in 3D modeling software, 3D-print the prototypes, and test the robot’s performance with respect to speed, traction, and ability to overcome obstacles. All three courses require that students follow the engineering design process, collect data, analyze data, visualize data, make decisions based on data, communicate and justify their ideas, use foundational mathematics in context, and follow relevant science practices.

Method

To investigate the engineering middle school courses' impact on students, the current study employs a mixed-methods research design in which both quantitative and qualitative data are collected and analyzed independently. Particularly, *mixed-methods sequential explanatory design* is used to expand and explain the findings of quantitative data (Creswell & Plano-Clark, 2011). In the explanatory design, the qualitative data collection emerges from quantitative results. Studies utilizing explanatory design take place in two sequential phases, with the quantitative data collection and analysis occurring first and usually providing the overall importance of the study. The benefit of such a design is that the quantitative data and the analysis provide a general understanding of the research results; however, the qualitative data and their analysis explain the statistical results by exploring participants' views in more depth (Creswell, Plano Clark, Gutmann, & Hanson, 2003). Thus, in this study, quantitative assessment and survey data serve as the primary data source with qualitative student interview data serving as a supplemental data source intended to help explain quantitative results.

Context of the Study and Participants

The study was conducted in a public school district in Georgia. Participants consisted of 6th-8th grade students (ages 11 through 14) at four middle schools. Approximately 67% of the students qualify for free/reduced lunch, and the race/ethnicity subgroups are White (45%), Black (46%), Hispanic (6%), and Other (4%). Because only two of the middle schools have implemented the engineering courses for three years, only data from those two schools are included in these analyses. Participants in the study included approximately 2,129 students; 1,153 enrolled in the semester-long engineering course during the 2015-2016 school year, and the other 976 were not enrolled and were available as a comparison group. The two engineering teachers were both beginning teachers who had not previously taught an engineering course. They received professional development on Project-Based Inquiry Learning, LEGO robotics, individualized instruction on the course curriculum, and regular ongoing and regular support through email, phone, and classroom visits.

A comprehensive database was developed to track and support the analysis of the longitudinal data collected for this research and to store information related to program dosage (e.g., how many engineering courses students took during their middle school years). Additionally, using unique student identification numbers in the database allows linking students' demographic information, number of times students were enrolled in the engineering course, measures of achievement, and survey responses across the duration of the program, thus enhancing the capacity to assess the relationship between program dosage and student outcomes.

Data Sources

State-Level Achievement Test

The measure of mathematics and science learning for this study was the Georgia Milestones Assessment System. This assessment is administered statewide to the students in grades 3 through 8. The description of the test states that it is a criterion-referenced test, although it also includes norm-referenced items to "complement the criterion-referenced information and to provide a national comparison" (Georgia Department of Education, 2016, p. 1). The assessment system provides student results as Achievement Levels and Scale Scores. The four achievement levels are: Beginning Learner, Developing Learner, Proficient Learner, and Distinguished Learner. The general meanings of each of the four levels are: Beginning learners do not yet demonstrate proficiency, Developing learners demonstrate partial proficiency, Proficient learners demonstrate proficiency, and Distinguished learners show advanced proficiency in the knowledge and skills necessary at that grade level. Scale scores are also provided, allowing comparisons within each grade level and content area. Scale scores range from 140 to 830. Table 2 below shows the content that is covered in the mathematics and science assessments for 8th grade.

Table 2. Domain structure for 8th grade milestones assessment

Grade level	Mathematics Milestones	Science Milestones
8th	Numbers, expressions, and equations Algebra and functions Geometry Statistics and probability	Structure of Matter Force and motion Energy and its transformation

The Student Survey

A student survey was developed and examined for construct validity with a middle school population in 2013 for the purpose of measuring change in specific 21st Century Skills and other non-cognitive student attributes. The instrument consists of 51 Likert-type self-report items in which students are asked to describe their level of agreement. The response options range from "Strongly Disagree" (=1) to "Strongly Agree" (=4). For the purpose of this paper, only the constructs presented in the table below are analyzed, each of which shows very good reliability based on Cronbach's alpha (>0.80) (Field. 2009).

Table 3. Cronbach's alphas for each construct measured through the student survey

Construct Category	Construct	Cronbach's alpha
Engagement	Cognitive Engagement	0.91
	Behavioral Engagement	0.84
	Emotional Engagement: Technology	0.90
	Emotional Engagement: Mathematics	0.93
	Emotional Engagement: Science	0.92
Self-efficacy	Self-Efficacy in Academics	0.88
Interest	Mathematics Interest	0.90
	Science Interest	0.88
Anxiety	Science Anxiety	0.88
	Mathematics Anxiety	0.90

Definition of the Student Survey Constructs

Engagement: Three types of engagement are captured by the student survey: Behavioral, Cognitive, and Emotional (Fredericks, Blumenfeld, & Paris, 2004). First, *Behavioral Engagement* is defined as positive conduct, such as paying attention and following rules. An example item from this construct asks for students' level of agreement with the statement: "I pay attention in class." This construct included items about school and classes in general as well as items in each content area: mathematics, science, and technology. Items for this construct were adapted from the *School Engagement Scale* (Fredericks, Blumenfeld, Friedel, & Paris, 2005). Second, *Emotional Engagement* is related to student affect, such as being interested, excited, or bored by classroom activities. This construct was also adapted from the *School Engagement Scale* (Fredericks et al., 2005). Because emotional engagement in the STEM-ID course was of particular interest for this study and can be impacted by the level of student interest in a particular subject areas, this construct was captured separately for all three content areas: science, mathematics, and technology. An example item from this construct is: "I feel excited by the work in math class." Finally, *Cognitive Engagement* has a broad description in the literature, encompassing students' desire to put effort into learning and school activities, as well as seeing the benefits of such activities. This construct was adapted from the *Science Motivation Questionnaire* (Glynn, Taasoobshirazi, & Brickman, 2009) and included such items as: "School is important for achieving future goals."

Self-Efficacy: Bandura (2006) defines self-efficacy as a self-judgment about one's ability to perform a task within a specific domain. This construct was defined in the survey as students' self-perception of their ability to understand difficult ideas in science, mathematics, and technology classes. These items were adapted from the *Science Motivation Questionnaire* (Glynn et al., 2009); for example: "I can understand ideas quickly in technology class" and "I am confident I will do well on science tests."

Interest: This factor focuses on both interest and personal relevance that students see in the content that they are learning. The items are focused on mathematics and science interest. Mathematics items were adapted from the *Mathematics Anxiety Scale-Revised* (Haiyan et al., 2009). Science items were adapted from the *Science Motivation Questionnaire* (Glynn et al., 2009). They include such items as "Math is one of my favorite subjects" and "Understanding science gives me a sense of accomplishment."

Anxiety has two components: feeling nervous and worrying. Feeling nervous is the uneasy or sick feeling students may get when they think about their schoolwork, assignments, or exams. Worrying is their fear about not doing very well in their schoolwork, assignments, or exams. Anxiety in this study was measured through surveys about both science and mathematics. In the literature, both anxiety measures address negative and positive feelings associated with mathematics and science, such as performing poorly on exams, or finding the topic interesting (Glynn & Koballa, 2006; Bai, Wang, Pan, & Frey, 2009). This study is focused on only negative aspects of anxiety associated with mathematics and science. These items were adapted from the

Science Motivation Questionnaire (Glynn et Al., 2009), and the *Mathematics Anxiety Scale-Revised* (Haiyan, LihShing, Wei, & Frey, 2009). Example items include: "I worry about my ability to solve math problems" and "Science makes me feel confused."

The complete lists of the survey items for each construct are included in Appendix A.

Student Interview Protocol

All interviewers used the same semi-structured interview protocol with follow-up questions to elicit rich data that could be subjected to sequential qualitative analysis (Miles, Huberman, & Saldana, 2014). The interview protocol was designed around several themes, including students' understanding of the engineering design process, their perceptions about the course, and the mathematics and science connections. Of these themes, only results from mathematics and science connections are presented in this study. Specifically, students were asked how the engineering course supports their understanding of mathematics and science skills. Some of the sample questions are: "How does testing designs in STEM-ID compare to activities you do in your science class? Do you think the science that you learn in your engineering class helps in your math class?"

Data Collection

Survey Administration: The surveys were administered to all students at all four middle schools at the beginning of the 2014-2015 and 2015-2016 academic years. In addition, students enrolled in the engineering courses at each school were administered a post-survey at the conclusion of the Fall semester and pre/post-surveys at the beginning and end of the Spring semester.

Interviews: All interviews were conducted in person by one of four members of the research team. Interviews took place in a quiet area of the school and lasted 15-20 minutes. With student permission, interviews were audio-recorded and transcribed for analysis. Students who were enrolled in the semester-long engineering courses during the 2015-2016 school year were interviewed at the end of the semester. Students were stratified into one of three groups based upon their academic performance on the Math and Science Milestones test and then randomly invited to participate within each of these achievement categories so that equal representation was maintained.

Sample

Sample Sizes in Academic Achievement (Science and Mathematics Milestones) & Surveys: The sample sizes for the quantitative analyses are presented in Table 4. The focus of the analyses is upon 8th graders because over the three years that the engineering course has been offered this group had the greatest range of attendance levels, ranging from no engineering course attendance to engineering course attendance during all three years of middle school. Because only two of the four middle schools in the school system have implemented the engineering course for three years, only data from these two schools, referred to as School A and B, are included in the analyses. The demographic characteristics of this sample are similar to that of the schools' characteristics overall. For example, females are slightly more represented in the Science Milestones sample, with 51% female and 49% male. Ethnically, 49% of the sample is Black, 36% is White, 8% is Latino, 5% is multi-racial, and the remaining 2% are either Asian or other ethnicity categories. These ethnicity proportions indicate that students who are Black were slightly more represented in the study sample than in the general district population (46% in the district) and White students are slightly less represented (45% in the district).

Table 4. Number of 8th grade students in schools A and B.

Attendance Level over Three Years	Mathematics Milestones Test	Science Milestones Test	Student Survey
No Engineering Course	48	51	38
One Year of Engineering Courses	103	114	77
Two Years of Engineering Courses	81	94	56
Three Years of Engineering Courses	40	64	50
Total	272	323	221

Note: Student survey sample sizes might differ slightly per construct analysis depending on data availability for that construct. Attendance level refers to number of engineering courses taken.

Sample Sizes in Qualitative Interviews: Ninety-two students were interviewed at the end of the 2015-2016 school year. Males represented 51% of the interview participants while females represented 49% of the participants. The demographics of this sample are also representative of the school district as a whole.

Data Analysis

Analysis of Academic Achievement (Milestones): A descriptive analysis was conducted of the impact of engineering course attendance on mathematics and science scores. Additionally, tests of statistical significance were conducted to determine the extent of differences in academic achievement between students in each attendance level using analysis of variance (ANOVA) with post-hoc tests employing Tukey's honest significant difference (HSD).

Relationship of Non-Cognitive Characteristics to Engineering Course Attendance: A regression analysis was conducted to determine the relationship of each of the non-cognitive constructs measured through the Student Survey and engineering course attendance, as described in the following equation.

$$\textit{Fall 2016} = \beta_0 + \beta_1(\textit{Years in engineering course}) + \beta_2(\textit{Fall 2015}) + e$$

In this equation, the *Fall 2016* variable represents the value for the non-cognitive construct, ranging in value from 1 to 4. Through this equation, this construct is being predicted by the number of *Years* that the student was enrolled in the engineering course, controlling for the value of the construct at the beginning of the preceding year, represented by *Fall 2015*. The variable *Years* indicates the number of years that the student had been in the engineering course by the conclusion of the 2015-2016 school year and could take the value of 0, 1, 2, or 3. The parameter estimate that is of interest for this report is the slope associated with *Years in engineering course*, which is represented by β_1. This parameter estimate indicates the change in the *Fall 2016* construct with each one-year increase in attendance, after controlling for a student's *Fall 2015* construct. A significant value for this parameter indicates a significant change in the slope as a result of attendance in the engineering course.

Qualitative Analysis: The NVIVO (2015) software program was used to code and analyze the student interviews. The interview coding process proceeded in three phases. In the first phase, a structural coding approach (Saldana, 2009) was utilized to categorize student responses according to the major topic areas included in the interview protocol. These categories were largely mutually exclusive due to the structure of the interview protocol; however, responses were coded into multiple categories as necessary. In the next phase of coding, two coders applied a provisional list of start-codes to a cross-sectional sample of six interview transcripts (two interviews from each grade level). This set of provisional codes was then revised to create a codebook that was then applied to code the full sample of interviews. Codes relevant to the sample of interview data reported in this study focused on identifying instances in which students discussed connections between their engineering class and their mathematics or science classes, and student responses indicating transferring knowledge between engineering and their mathematics or science classroom. The codebook included both positive and negative codes to capture instances where students either affirmed or denied such connections or knowledge transfer.

Results

Student Achievement

Results from the one-way ANOVA showed a statistically significant difference between the group means of those in each attendance level for both Mathematics Milestones ($F(3,268)=11.32$, $p<.0001$) and Science Milestones ($F(3,319)=17.17$, $p<.0001$). Post-hoc tests set at a 95% confidence level ($p<.05$) indicate that students who have taken at least two engineering courses showed statistically higher science and mathematics test scores compared to those students who were never enrolled in these courses. In other words, students' academic performance on the Milestones assessment was significantly higher among those students who attended engineering courses for at least two years compared to those who have attended one year and those who experienced no engineering course. Figure 2 presents the average Milestone scores per attendance group for each of the groups described earlier, specifically focusing on the 8th grade students.

Effect sizes for these analyses were calculated through eta-squared, which is the proportion of the variance that is explained by the model. Cohen's (1988) guidelines on interpreting this effect size for ANOVA are that a value of 0.01 is considered small, 0.06 is medium, and 0.14 is large. The effect sizes for the Milestones analyses were determined to be 0.11 for Math Milestones and 0.14 for the Science Milestones, both of which fall near or at the large range.

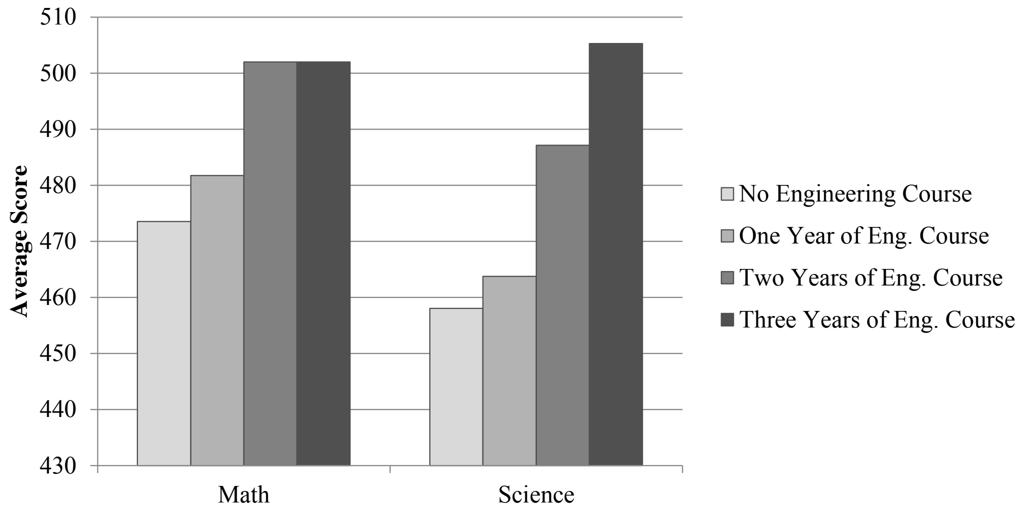

Figure 2. Average math and science milestones scores per engineering course attendance level

When examining the distribution of students in each of the Milestones achievement levels, for each engineering course attendance group the improvement in achievement is also apparent. For both Mathematics Milestones and Science Milestones, the percentages of students in the Developing and Proficient categories are larger among higher-attendance groups compared to lower-attendance groups. Similarly, those in the Beginning category show substantially smaller percentages among higher-attendance groups compared to lower-attendance groups. These patterns are particularly pronounced among those who attended at least two years of the engineering course. The percentages are presented in Figure 3 and Figure 4.

Middle school students in this school system are generally placed in elective "connections" classes randomly during the scheduling process. However, in these analyses of student achievement, of particular concern was whether there were sub-populations of students who were either disproportionately enrolled, or not enrolled, in the engineering course in a systematic way that could result in an overrepresentation of these individuals within attendance groups. This overrepresentation subsequently could have an effect on the average scores for these groups. Three sources of potential bias were identified. The "enrichment" classes, which also were assigned randomly, had the purpose of improving mathematics and science academic performance, and could introduce bias. Overrepresentation in the engineering classes of honors students, or underrepresentation of remedial students, would also skew the data. This was of particular concern since students in the remedial mathematics program are redirected into remedial classes, rather than taking standard connections classes such as engineering.

To determine if there was disproportional representation, an examination was conducted of the proportion of students in each of the attendance categories per level of attendance. Results indicated that equivalent representations of students in enrichment classes were found across attendance levels; however, an overrepresentation of honors students was found among those with higher attendance levels (i.e., two years and three years of engineering course attendance) and an overrepresentation of students in remedial classes was found among those with lower attendance levels (i.e., no engineering course attendance and one-year of engineering course attendance). For this reason, multiple analyses were conducted without members of each of these groups to control for the potential effect of these students on analyses of average Milestones scores. In each analysis, statistically significant differences between the groups remained for both Math and Science Milestones, regardless of whether honors students were removed ($F_{math}(3,257)=9.80$, $p<.0001$; $F_{science}(3,266)=10.38$, $p<.0001$), remediation students were removed ($F_{math}(3,91)=6.58$, $p=.0005$; $F_{science}(3,128)=9.50$, $p<.0001$), or both honors and remediation students were removed ($F_{math}(3,84)=5.07$, $p=.0028$; $F_{science}(3,88)=5.04$, $p=.0029$).

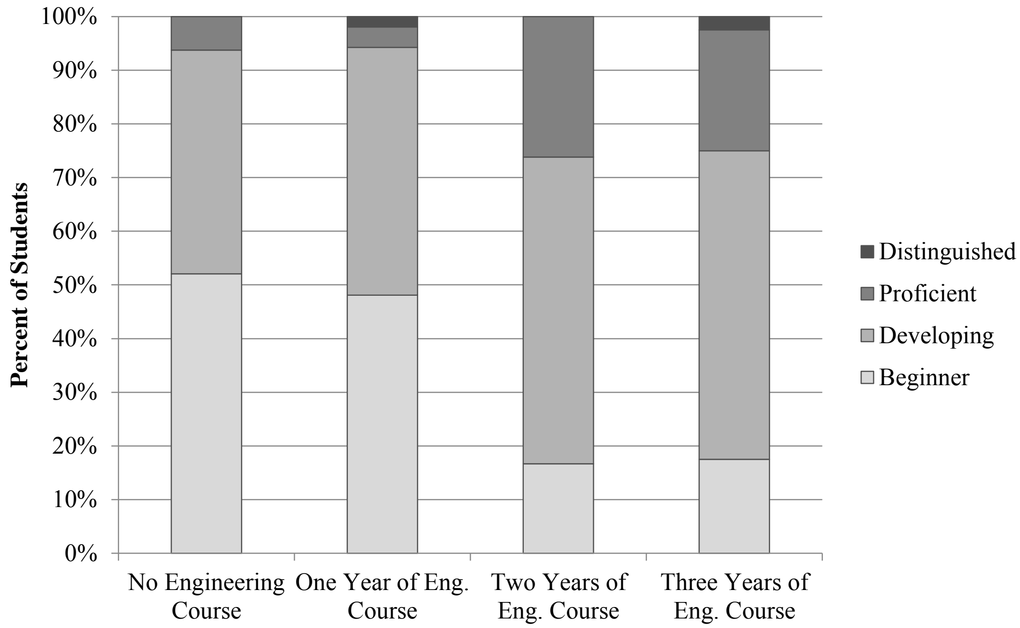

Figure 3. Achievement Levels for Math Milestones per Engineering Course Attendance Level

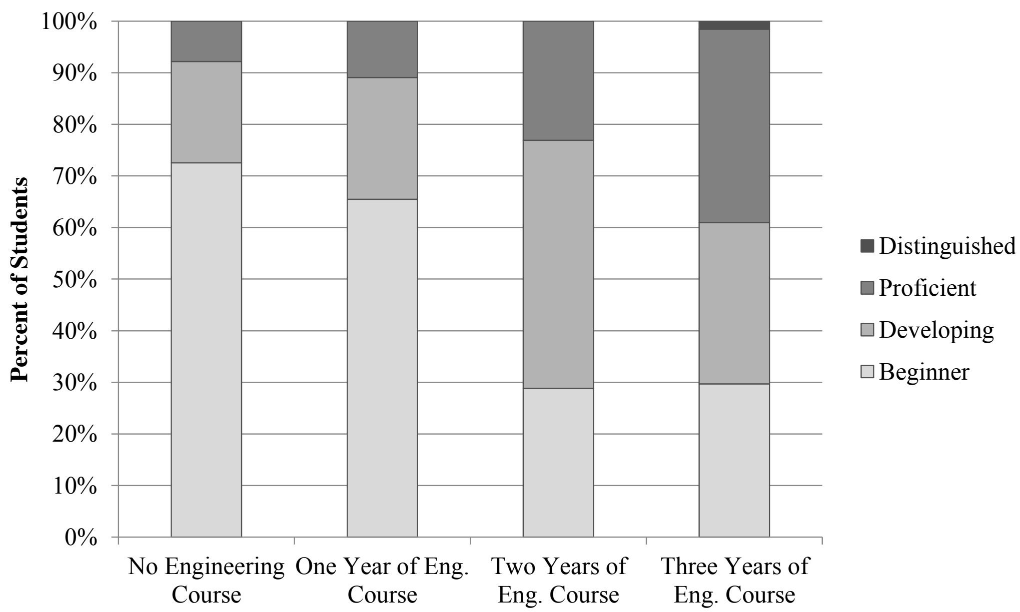

Figure 4. Achievement levels for science milestones per engineering course attendance level

Relationship of Non-Cognitive Characteristics to Academic Performance

Significant treatment effects of attendance in the engineering course (β_1) estimated through the regression equation described in the data analysis section above are presented in this section. The results of regression analyses indicate that the number of years attending the engineering course significantly predicted two measures of engagement: Behavioral and Cognitive Engagement, as well as Science Interest. In other words, for each year of the engineering course that students attend, a significant increase in each of these constructs was found. The regression coefficients for each of these analyses are presented in Table 5.

Table 5. Regression estimates of the effect of attendance in engineering course on student constructs (*n*=160)

Variable (Construct)	β_1	*B*	*SE B*	R^2	*p*
Cognitive Engagement*	.080	.15	.038	.25	.037
Behavioral Engagement**	.075	.19	.026	.31	.005
Emotional Engagement: Technology	.065	.097	.052	.12	.22
Emotional Engagement: Mathematics	-.036	-.056	.046	.28	.42
Emotional Engagement: Science	.082	.13	.046	.16	.076
Self-Efficacy in Academics	.055	.13	.029	.32	.062
Mathematics Interest	-.036	-.047	.049	.36	.47
Science Interest*	.075	.15	.035	.25	.036
Mathematics Anxiety	.028	.051	.037	.33	.45
Science Anxiety	-.049	-.085	.043	.20	.25

*$p < .05$; ** $p < .01$. Note: Sample sizes for regression analyses were smaller than those presented in Table 4 due listwise deletion.

Students' engagement in school often declines as they advance from elementary to middle school and again in the transition to high school (Brewster & Fager, 2000). Thus, the engineering course impact on student engagement is a very important result. Although the impact of the course on measures of Emotional Engagement was not found to be statistically significant through the regression analyses, ANOVA results indicated that Emotional Engagement in Science and in Technology were statistically different between attendance groups ($F(3,202)=2.91$, $p=.04$, eta-squared = 0.041; $F(3,200)=2.81$, $p=.04$, eta-squared = 0.040, respectively). Effect sizes fall between small and medium. Additionally, a positive pattern in these measures is apparent in Figure 5. Students who attended multiple years of the engineering course showed higher average ratings of engagement in technology and science than those students who attended only one year of the course or not at all. The largest differences are apparent in the comparisons of the one-year and the three-year attendance groups. The three-year attendance group had average ratings of Science Engagement that were 0.5 points (17%) higher than those who attended only one-year, Technology Engagement that were 0.42 points (14%) higher, and Science Interest that were 0.33 points (11%) higher than those who attended only one year.

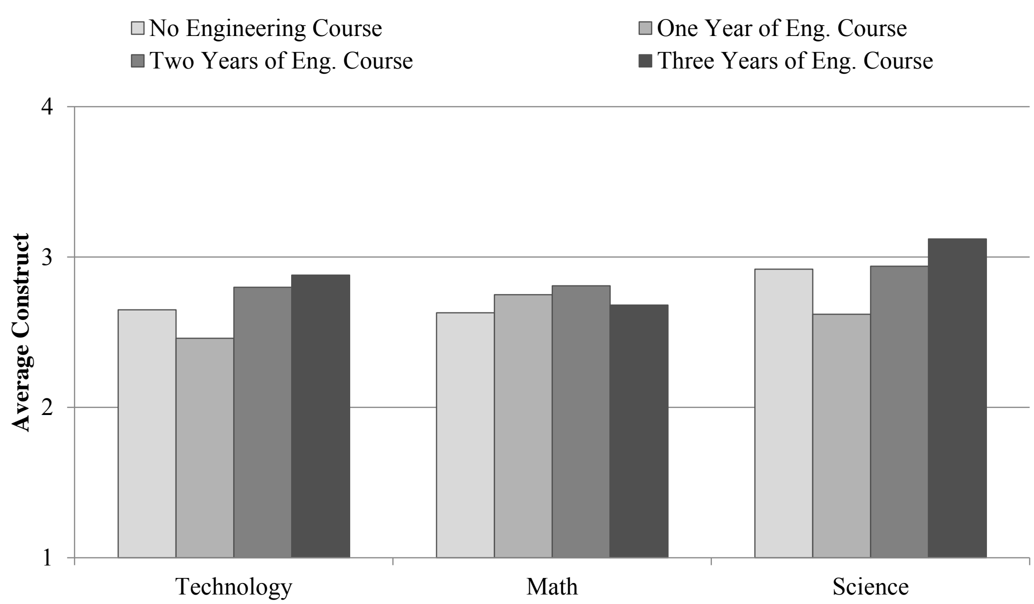

Figure 5. Mean Scores on each Construct among 8th Grade Students of Emotional Engagement per Engineering Course Attendance Level

It is assumed that once students become engaged in any one of these three areas, they will seek to make improvements over time, not just in the one area, but in the other two areas as well (Fredricks, Blumenfeld, & Paris, 2004). For instance, it is likely that emotional engagement leads to increases in behavioral and cognitive engagement, which subsequently leads to academic achievement. Further, both behavioral and cognitive engagement have been tied to motivation in the research literature (Fredricks et al., 2004). Emotional engagement has been tied to individual psychological needs. The extent that students' environment meets the fundamental psychological needs for relatedness, autonomy, and competence determines the degree of engagement. There is evidence from a variety of studies suggesting that engagement positively influences achievement. Research shows that there is a positive correlation between behavioral engagement and achievement-related outcomes such as standardized tests and grades on all grade levels (Connell, Spencer, & Aber, 1994; Connell & Wellborn, 1991; Marks, 2000; Skinner, Wellborn, & Connell, 1990).

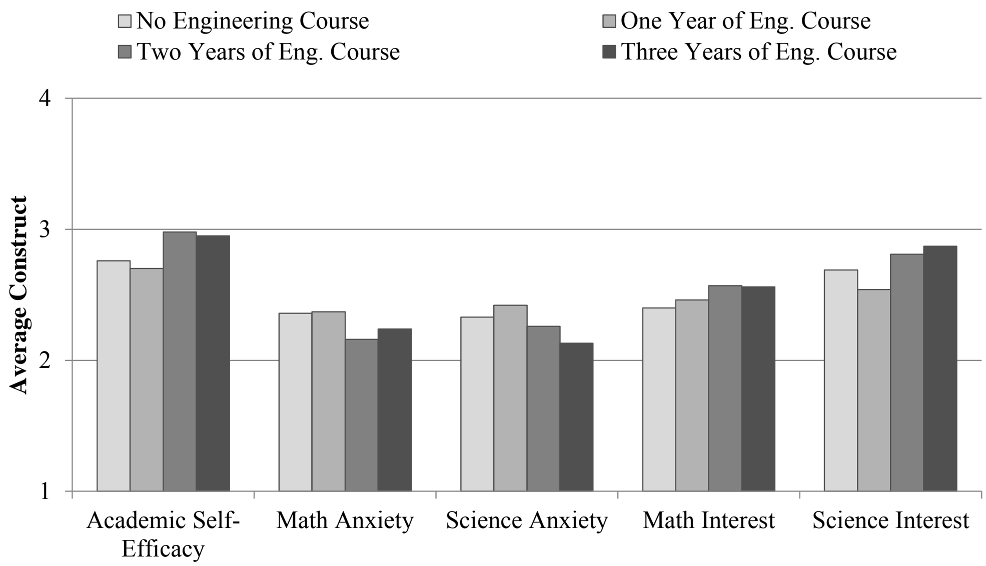

Figure 6. Mean scores on each construct among 8th grade students per engineering course attendance level

Mean scores of ratings of the remaining non-cognitive constructs are presented in Figure 6. Academic Self-Efficacy is one of the constructs illustrated that show higher ratings among those students who attended the engineering course for two and three years compared to those who attended one year or not at all. Further, an ANOVA analysis of the average constructs between the different attendance groups revealed significant differences (F (3, 204) =2.79, p=.04, Effect Size: 0.039). Bandura (1977) hypothesized that both the choice of activities and the level of persistence in those activities were affected by self-efficacy. "The tendency for efficacious people to 'expend more effort and persist longer' is of particular importance because most personal success requires persistence effort" (Artino, 2012, p. 78). Particularly, student self-efficacy in academics is very important, because it affects student persistence in long-term education goals.

Figure 6 also reveals patterns in science- and mathematics-related constructs. Although Science Anxiety and Math Anxiety constructs were not significant, they are lower among students who attended for two or three years of the engineering course compared to those who attended only one year or not at all. As anxiety is lower, Science Interest and Math Interest are higher among those with higher attendance levels, with those attending two and three years showing higher average construct values compared to those who attended for one year or not at all. As indicated through the regression analysis presented in Table 5, only the increase in Science Interest was significant. This result suggests that the engineering course makes science more relevant to students, and hence increases their interest in science. The science interest construct is focused on personal relevance and interest.

Student Interviews

Connections to Mathematics and Science

Across grade levels and schools, consistent with quantitative results, interview data suggest that students are able to transfer knowledge between the engineering course and their core mathematics and science courses. Students discussed their use of mathematics skills in the engineering course during the design challenge, with explicit references to how applications in their engineering class helped them in their mathematics class. This tendency is evident in the following student reflection on the carnival game challenge:

> When we did the carnival game we had to find the percentage of how many times it will make it into the big prize zone or the small prize zone and I was having trouble with proportions and we had to do proportions to find the percentage. And that helped me a lot because I got proportions good in my math class after I did that.

Similarly, consider the following student's discussion of transferring knowledge between mathematics and science classes:

> Yeah, because when you do her math in your class and then the next day you might get a math problem and be, oh, I just did this in technology class and you can go back and apply it. It helps me out a lot because most of the times I get my math problems right from what she's taught me in her class.

Students viewed the engineering courses as a place where they can put their science and mathematics knowledge into practice, describing ways in which the engineering course may be reinforcing what they are learning in the mathematics and science classrooms. As one student described, "it helps my math and science classes. Kind of but mostly the math classes doesn't relate to engineering the engineering relates to math like it's backwards kind of." Another student discussed how learning engineering skills helps his/her understanding of science and mathematics more and how he/she transfers knowledge between two classes:

> In my math class, I'm learning this stuff so I can take it back to engineering, and the stuff I learn in engineering, I get a bender. Whenever we're learning in class, I'm just like, 'Okay, I don't understand that.' I go to engineering, and using the things makes me better understand it, so I can go back to math class and ace the tests.

Additionally, consistent with the quantitative results, students discussed their understanding of the engineering design process, which suggests that the students have a solid sense of what engineers do (i.e., identify user needs, design, test, build, and iterate). Further, students discussed how scientific thinking is very similar to the EDP process, which helps them with their critical thinking skills to solve a problem.

> The scientific method is kind of like the same thing. You have to find out what the problem is, then you have to brainstorm ideas, and then after you brainstorm, you have to make up different concepts and if those don't work, … no, you have to make a hypothesis before that. You have to make a hypothesis, you have to figure out what you think will work better, like we did in the engineering class, like the circle base or the square.

Students' reflections on their experiences in the engineering course highlight the connections between their engineering courses and their core science and mathematics courses, making it clear that students were able to transfer knowledge and skills between the engineering and science and mathematics courses.

Conclusion and Discussion

The results of this study support the hypothesis that enabling students to practice their foundational science and mathematics skills within the context of interesting and engaging middle school engineering classes can significantly benefit their engagement and academic achievement in mathematics and science. In particular, the results of the current study show that these engineering courses, run in parallel with the core science and mathematics classes for multiple years, can help students who struggle in STEM classes significantly improve their science and mathematics achievement scores. It is difficult to decipher whether these improvements in scores, particularly the dramatic decrease in the number of students in the "beginner" level of achievement, reflect an increase in mathematics and science mastery or instead are a result of increased student engagement with school and with the standardized test-taking process. The study also does not address which features of the courses—i.e., the level of integration or interdisciplinarity, the time provided for hands-on practice of foundational mathematics and science skills, the engaging contexts, or the low-pressured environment—are most important. In the end, the cause of the change is less important than the fact that more students from low-achieving and vulnerable populations are experiencing, and reporting, more success in STEM and in school.

Additionally, this study verifies the results of previous studies. For example, Cantrell et al. (2006) investigated an impact of a program, Integrating Engineering into Science, and concluded that engaging students in engineering curriculum activities may reduce achievement gaps in science. Further, their study showed that the engineering design process motivates students to learn science and mathematics and is beneficial to students with different backgrounds. Similar to the Cantrell et al. (2006) study, results from Rishowski et al. (2009), a study about implementing engineering design projects in an 8th grade science class, showed that students showed statistically significant improvement in content knowledge. Although there are numerous studies regarding integrating the engineering design progress into science classes and how it impacts student learning, there are not many interventions and results regarding a semester-long engineering class, specifically students' ability to transfer knowledge between core courses and engineering courses. Our study sheds light on how enabling students to practice their foundational science and mathematics skills within the middle school engineering classes can significantly benefit their engagement and academic achievement in mathematics and science.

Limitations to the Study

Although the research has reached its aims, there were some limitations to the study. First, self-reported data were collected to measure non-cognitive skills. Self-reported data have many advantages, but they also suffer from potential bias due to people's motivations at the time they filled out the questionnaire. Second, qualitative data were collected to supplement the quantitative results and to help describe students' perceptions of knowledge transfer and the nature of content connections between engineering, science, and mathematics classes. This type of analysis provides a valuable window into student thinking, but is limited in its ability to explain the degree of the transfer or the specific content connections students are making. Finally, there are some limitations in the research design. Quantitative analysis served as the main source to answer the research questions. As part of the mixed- methods sequential explanatory design, qualitative methods are used to assist in explaining quantitative results; hence the qualitative components are small and complementary to the overall quantitative design.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 1238089. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation or Georgia Institute of Technology. For additional information about the research related to this project see https://ampitup.gatech.edu.

References

Artino, A. R. (2012). Academic self-efficacy: from educational theory to instructional practice. *Perspectives on Medical Education*, *1*(2), 76-85. doi:10.1007/s40037-012-0012-5

Bai, H., Wang, L., Pan, W., & Frey, M. (2009). Measuring mathematics anxiethy. Psychometric analysis of bidimensional affective scale. *Journal of Instructional Psychology*, 36, 185-193.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191-215.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajeres & t. Urdan (Eds.) *Self-efficacy beliefs of adolescents*, *5*(307-337).Greenwish, CT: Information Age Publishing.

Barrows, H. S. (1985). *How to design a problem-based curriculum for the preclinical years* (Vol. 8): Springer Pub Co.

Bransford, J. D. (1999). How people learn: Brain, mind, experience, and school. Washington, DC: Committee on Developments in the Science of Learning: Commission on Behavioral and Social Sciences and Education, National Research Council, National Academy Press.

Brewster, C., & Fager, J. (2000). Increasing student engagement and motivation: From time-on-task to homework. Northwest Regional Educational Laboratory. Retrevied April, 2016, from http://www.educationnothwest.org/sites/default/files/byrequest.pdf

CAD 200: computer aided design software and utilities [Computer software]. (n.d.).

Cantrell, P., Pekcan, G., Itani, A., & Velasquez-Bryant, N. (2006). The effects of engineering modules on student learning in middle school science classrooms. *Journal of Engineering Education*, *95*(4), 301-309. doi:10.1002/j.2168-9830.2006.tb00905.x

Carberry, A. R., Lee, H.-S., & Ohland, M. W. (2010). Measuring engineering design self-efficacy. *Journal of Engineering Education*, *99*(1), 71-79. doi:10.1002/j.2168-9830.2010.tb01043.x

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. New York, NY: Routledge Academic.
Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Erlbaum.
Connell, J. P., Spencer, M. B., & Aber, J. L. (1994). Educational risk and resilience in African-American youth: Context, self, action, and outcomes in School. *Child Development*, *65*(2), 493-506. doi:10.1111/j.1467-8624.1994.tb00765.x
Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relatedness: A motivational analysis of self-system processes. . In M. Gunnar & L. A. Sroufe (Eds.), *Minnesota Symposium on Child Psychology* (Vol. 23). Chicago: University of Chicago Press.
Council, N. R. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*: National Academies Press.
Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Los Angeles: Sage.
Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods designs. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 619-637). Thousand Oaks, CA: Sage.
Dawes, L., & Rasmussen, G. (2007). Activity and engagement – keys in connecting engineering with secondary school students. *Australasian Journal of Engineering Education, 13*(1), 13-20. doi:10.1080/22054952.2007.11464001
Field, A. (2009). *Discovering statistics using SPSS* (Third ed.): Sage publications.
Fishman, B. J., Penuel, W. R., Allen, A.-R., Cheng, B. H., & Sabelli, N. (2013). Design-based implementation research: An emerging model for transforming the relationship of research and practice. *National Society for the Study of Education*, *112*(2), 136-156.
Fredericks, J. A., Blumenfeld, P., Friedel, J., & Paris, A. (2005). School engagement. In K. A. Moore & L. Lippman (Eds.), *What do children need to flourish?: Conceptualizing and measuring indicators of positive development*. New York: Springer Science and Business Media.
Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of educational research*, *74*(1), 59-109.
Georgia Department of Education. (2016). *Georgia Milestones Assessment System: End-of-Grade (EOG) Interpretive Guide for Score Reports for Spring and Summer 2016*. Retrieved from https://www.gadoe.org/Curriculum-Instruction-and-Assessment/Assessment/Documents/Milestones/EOG-Resources/EOG_2016_Score_Interpretation_Guide.pdf
Glynn, S. M., Koballa, T. R. Jr. (2006). Motivation to learn collece science. In J.J. Mintzes & W.H. Leonard (Eds.), Handbook of college science teaching (pp. 25 – 32). Arlington, VA: National Science Teachers Association Press.
Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science Motivation Questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching*, *46*(2), 127-146. doi:10.1002/tea.20267
Haiyan, B., LihShing, W., Wei, P., & Frey, M. (2009). Measuring mathematics anxiety: psychometric analysis of a bidimensional affective scale. *Journal of Instructional Psychology*, *36*(3), 185-193.
Hmelo-Silver, C. E., & Pfeffer, M. G. (2004). Comparing expert and novice understanding of a complex system from the perspective of structures, behaviors, and functions. *Cognitive Science*, *28*(1), 127-138. doi:http://dx.doi.org/10.1016/S0364-0213(03)00065-X
Illustrative Mathematics. (2014). *Standards for Mathematical Practice: Commentary and Elaborations for K–5*. Tucson, Arizona.
Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., . . . Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design(tm) into practice. *Journal of the Learning Sciences*, *12*(4), 495-547. doi:10.1207/S15327809JLS1204_2
Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences*, *7*(3), 313.
Marks, H. M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*, *37*(1), 153-184. doi:10.3102/00028312037001153
Mehalik, M. M., Doppelt, Y., & Schuun, C. D. (2008). Middle-School science through design-based learning versus scripted inquiry: Better Overall science concept learning and equity gap reduction. *Journal of Engineering Education*, *97*(1), 71-85. doi:10.1002/j.2168-9830.2008.tb00955.x

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). Qualitative data analysis: A method sourcebook. *CA, US: Sage Publications*.
National Research Council (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. The National Academies Press. Washington, D.C.
National Research Council (2014). STEM integration in K-12 education: Status, prospects, and an agenda for research. The National Academies Press. Washington, D.C.
NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington DC: National Academies Press.
NVivo qualitative data analysis Software; QSR International Pty Ltd. Version 11, 2015.
Rishowski, J. L., Todd, C. D., Wee, B., Dark, M., & Harbor, J. (2009). Exploring the effectiveness of an interdisciplinary water resources engineering module in an eight grade science course. *International Journal of Engineering Education*, *25*(1), 181-195.
Saldana, J. (2009). An introduction to codes and coding. *The coding manual for qualitative researchers*, 1-31.
Skinner, E. A., Wellborn, J. G., & Connell, J. P. (1990). What it takes to do well in school and whether I've got it: A process model of perceived control and children's engagement and achievement in school. *Journal of Educational Psychology, 82*(1), 22-32. doi:10.1037/0022-0663.82.1.22
Spelt, E.J.H., Biemans, H.J.A., Tobi, H., Luning, P.A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: Asystematic review. *Educational Psychology Review*, 21:365-378.
Tafoya, J., Nguyen, Q., Skokan, C., & Moskal, B. (2005). *K-12 outreach in an engineering intensive university [online]*. Paper presented at the 4th ASEE/AaeE Global Colloquium on Engineering Education, Brisbane, Queensland.

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Appendix A. Survey Items

Response options for each of the following statements ranged from "Strongly Disagree" (=1) to "Strongly Agree" (=4).

Cognitive Engagement (5 items)

I plan to continue me education following high school.
Going to school after high school is important.
School is important for achieving future goals.
My education will create many future opportunities for me.
I am hopeful about my future.

Behavioral Engagement (6 items)

I follow the rules at school.
I get in trouble at school. (reversed)
I pay attention in class.
I pay attention in technology class.
I pay attention in math class.
I pay attention in science class.

Emotional Engagement in Technology (3 items)

I am interested in the work in technology class.
I feel excited by the work in technology class.
I like being in technology class.

Emotional Engagement in Math (3 items)

I am interested in the work in math class.
I feel excited by the work in math class.
I like being in math class.

Emotional Engagement in Science (3 items)

I am interested in the work in science class.
I feel excited by the work in science class.
I like being in science class.

Self-Efficacy for Academics (10 items)

I am confident I will do well on science labs and projects.
I believe I can master the knowledge and skills in my science course.
I am confident I will do well on science tests.
I believe I can earn a grade of "A" in my science course.
I can understand difficult ideas in technology.
I can learn new ideas quickly in technology class.
I can understand difficult ideas in math.
I can learn new ideas quickly in math class.
I can understand difficult ideas in science.
I can learn new ideas quickly in science class.

Math Interest (3 items)

I find math interesting.
Math is one of my favorite subjects.
I enjoy learning mathematics.

Science Interest (7 items)

I enjoy learning about science.
The science I learn relates to my personal goals.
I find learning science interesting.
The science I learn is relevant to my life.
The course I learn has practical value for me.
I like science that challenges me.
Understanding science gives me a sense of accomplishment.

Science Anxiety (6 items)

I am nervous about how I will do on science tests.
I become anxious when it is time to take a science test.
I worry about failing science tests.
Science makes me feel nervous.
Science makes me feel confused.
I worry about my ability to learn science.

Math Anxiety (5 items)

My mind goes blank and I am unable to think clearly when doing my math test.
I worry about my ability to solve math problems.
I get a sinking feeling when I try to do math problems.
Mathematics makes me feel nervous.
Mathematics makes me feel confused.