# An Examination of Middle School Students' STEM Self-Efficacy with Relation to Interest and Perceptions of STEM

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## Abstract

The purpose of this teacher research study is to ascertain students' interest in STEM and beliefs about STEM before and after STEM specific instruction, explore possible differences in STEM self-efficacy by gender, and explore differences in STEM self-efficacy by group role. Our primary data sources include a modified attitudinal survey and modified perceptions of collaboration survey. We found differences in gender and students' group roles to be related to self-efficacy, intentions to persist in STEM, perceptions of STEM and interests in STEM. Research on students' self-efficacy and perceptions of group work has the potential to restructure how teachers design activities and teach students about collaboration.

## Introduction

Recent calls for widespread educational reforms are supported by evidence that US students are not adequately prepared for college, the work force, and our technologically advanced 21st century society (International Society for Technology in Education [ISTE], 2007; National Research Council [NRC] 2013; Partnership for 21st Century Skills, 2002). The situation is especially desperate in Science, Technology, Engineering, and Mathematics (STEM) education, where the demand for STEM professions and careers is scarcely lacking US candidates (U.S. Congress Joint Economic Committee, 2012). For the past 30 years, there has been a steady decline in the number of individuals entering science and engineering related fields. The annual growth rate for science and engineering jobs has doubled compared to other professions. However, national trends for attrition and retirement in the workforce project that the number of qualified US candidates entering the field is far below the amount needed to adequately meet the needs of the profession. The mismatch between qualified US candidates and the personal needs of the engineering field is partially attributed to retirement. The bulge of engineers established during the "Baby Boom" era (e.g., born between 1946-1964) will need to be replaced. The average age of the science and engineering laborer has increased from 37 to 41 since 1993 (NSF, 2012). Looking across degree fields, the average age of metallurgical, mineral, and mining engineers is over 50 (NSF, 2012). This trend indicates a substantial population of engineers nearing retirement.

This aging of the engineering workforce requires an urgent response to increase the number of students in STEM, and particularly engineering, career pathways. One significant factor to consider to help facilitate students' success in STEM education and professions is developing students' positive self-efficacy beliefs. Indeed, significant scholarship shows that students' self-efficacy beliefs are the foundation for entrance and persistence in the STEM profession. For instance, research documents that students' self-efficacy beliefs predicts students' intentions to persist in engineering (Schaefers et al., 1997; Concannon & Barrow, 2010), performance and ability to reach academic milestones (Pajares & Miller, 1994), one's perceived outcomes (Larose et al., 2006), and interest (Fouad & Smith, 1996).

In response to the need to encourage more students in STEM and build students self-efficacy beliefs, we have purposefully designed and planned instruction to engage and captivate students' interest in learning to promote long-lasting understanding and perseverance. In accordance with national reform, we have implemented lessons that are student-led, focus on meaningful interactions with data, and provide opportunities for students to construct claims based on scientific evidence (NRC, 2013). The purpose of this study is directly related to investigating the impacts of STEM instruction. The first goal of the study was to determine if STEM instruction has an impact on participants' attitudes, perceptions, beliefs, and self-efficacy. The second goal is to explore the interaction of factors that play a significant role in students STEM experiences.

## Theoretical Framework-Self Efficacy

In order to understand the factors that are important for STEM learning and persistence, researchers must identify important components of an individual's belief system. Self-efficacy is one of the most significant components of a student's belief system and strongly related to students persistence in STEM pathways (Concannon & Barrow, 2010). The concept of self-efficacy was first described by Bandura (1977) who explained that it is comprised of an individual's belief in their ability to perform and successfully complete a specific task. The task may refer to a multitude of actions; for example, a student's lack of confidence in his or her abilities to do well on a physics test stems from low self-efficacy.

Bandura (1997) explained that an individual's self-efficacy beliefs are derived from several sources. These sources of self-efficacy are: mastery experiences, vicarious experiences, verbal persuasions, and physical and emotional states. A person's mastery experiences (i.e. performance accomplishments) are the primary source for his or her development of positive self-efficacy beliefs (Bandura, 1997; Britner & Pajares, 2006). Self-efficacy theory documents that learning also is developed by observing others (e.g., vicarious learning) (Bandura, 1977). Individuals' vicarious learning experiences are complex and result from observing others' behaviors and how those behaviors produced desirable or undesirable outcomes. The self-efficacy theoretical framework is a useful guide for understanding students' belief systems and persistence in STEM

## Purpose

This is a two part quantitative study of middle school students' self-efficacy, beliefs about persistence, and attitudes towards group work before engaging in a STEM-related program. The first portion of the study was aimed at investigating the influence of STEM curriculum on student's beliefs and attitudes. This portion of the study was guided by the following two research questions:

Research Question One: Does an explicit approach to teaching science, technology, engineering, and mathematics have an effect on students' interests in STEM, students' perceptions regarding the usefulness of STEM, students' intentions to persist in STEM, and STEM self-efficacy?

Research Question Two: Does an explicit approach to teaching the nature of science, technology, engineering, and mathematics have an effect on students' perceptions of group work?

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The second portion of the study was exploratory in nature and designed to investigate the relationships between the subscales and important differences within the test population. This portion of the study consists of three additional research questions:

Research Question Three: Are students' STEM self-efficacy beliefs a significant predictor for students' intentions to persist in STEM?

Research Question Four: Are there statistically significant relationships among student subscale scores based on group experiences and group role?

Research Question Five: Are there statistically important gender differences within the test population?

## Literature Review

Experts in education agree that in order to promote science literacy and increase students' engagement in STEM, instruction should be student-led, focus on meaningful interactions with data, and provide opportunities for students to construct claims based on scientific evidence (NGSS Lead States, 2013). Indeed, research shows that when teachers focus on problem/project based learning, students significantly improve in student grades, attitudes, and motivation (Krajcik, Blumenfeld, Marx, & Solloway, 1994; Krajcik, Czerniak, & Berger, 2003; Gallagher, Stepien, Sher, & Workman, 1995; Rivet & Krajcik, 2004). While studies show that problem-oriented lessons engage students, a number of researchers have identified differences that occur within a classroom that lead to different learning experiences for students. Of the differences that occur within a classroom population, gender and self-efficacy differences are prevalent in STEM. The gap between female and male students' mathematics self-confidence begins in the middle school ages and widens through secondary education (Pajares, 2005). Girls' self-confidence in math and science is the foundation for building interest in STEM related areas [American Association of University Women (AAUW), 2010].

Prior research has shown that there are some differences in social-cognitive variables between boys and girls. For example, while Fouad & Smith (1996) did not find differences in self-efficacy by gender, there were differences in outcome expectations (boys being higher). The authors suggest that this may have a more direct consequence on boys' increased intentions to persist in math and science compared to girls (Fouad & Smith, 1996).

Looking specifically at the sources of middle school student self-efficacy beliefs, Britner and Pajares (2006) found that students' mastery experiences were the only source of self-efficacy to statistically predict science self-efficacy. Boys and girls had similar levels of self-efficacy beliefs despite that girls obtained higher grades. Interestingly, boys held significantly higher levels of mastery experiences and self-concept. Mastery experiences, as a source of self-efficacy, were found to be a better predictor for girls compared to boys. This more recent study aligns with prior studies such as Britner and Pajares (2001); Pajares, Britner, and Valiante (2000). Finally, Pajares, Britner, and Valiante (2000) found no relationship between gender and self-efficacy ($r = -.17$).

Catsambis (1994) examined gender differences in mathematics achievement and attitudes towards mathematics among middle school-aged students. Using 1988 National Center for Education Statistics data, Catsambis found no differences in mathematics achievement between genders. In fact, in some cases girls performed better than boys. Gender differences did exit in students' attitudes towards mathematics. Boys had significantly higher attitudinal scores toward mathematics despite a significantly greater number of girls than boys enrolled in an advanced level mathematics course. Additionally, a significantly greater number of boys were enrolled in the lower level mathematics course. Catsambis posits in her results that by eighth grade more boys than girls decide to pursue a mathematics and science career, and that white females are less likely to find mathematics useful or enjoyable. As explained in Mattern and Schau's (2002) study, girls' attitudes toward science develop independently from achievement. Similarly, Chen and Zimmerman (2007) examined middle school students' mathematics self-efficacy beliefs and found no correlation between gender and mathematics self-efficacy; however, girls reported feeling they exerted more effort than the boys and that boys were more confident that they solved mathematics problems correctly.

## Research Design

To better understand these participants' prior knowledge, beliefs, and experiences, we describe the unique content/participants, STEM curriculum, and data collection instruments, variables and analysis methods. The research design was quantitative in nature whereby data was analyzed using simple linear regression, multiple linear regression, and analysis of variance techniques.

### Context/Participants

A total of 206 (91 male, 115 female) sixth-grade students attending a suburban middle school participated in this study. The participants were all enrolled in a $6^{th}$ grade earth science course. At the time of data collection, students were in second semester and 7 months into the school year. In the course, students had studied earth and plate tectonics and were beginning their unit on space and the solar system.

### STEM Curriculum

Multiple project-based learning activities were used to engage students in learning space science topics. "Space systems" is highlighted as essential disciplinary core content in the K-12 Science Education Frameworks necessary to promote higher levels of science literacy in the USA (NGSS Lead States, 2013). The multiple project-based learning activities included two main space science components: (1) Virtual, synchronous online group activity and (2) a hands-on, field-based exploration. Both components are led by professional educators who have designed reform-oriented, standards-based space science curriculum. In addition, both main project-based learning activities required students to work together in cooperative teams to complete a project-based task. In this regard, the project-based activities promote the five basic elements of effective cooperative learning: positive interdependence, individual and group accountability, face-to-face interaction, interpersonal skills, and group processing (Johnson, Johnson, & Smith, 1991).

The virtual, synchronous online group activity engaged students in a problem-based scenario involving a settlement in space (lunar habitation) that is in danger of being hit by a comet. Students work with a specific team to collect and analyze data. The cooperative teams are as follows: the "comet tracking team" collects data as the comet is approaching and provides estimated times of impact and the distance reached by "ejecta;" the "Moon mapping team" calculates which location on the Moon has the highest probability of impact and the area of the impact; the "crisis management team" determines which base needs evacuation orders and executes those orders. They are responsible for moving equipment and personnel to safety and calculating the estimated arrival times of astronauts using various methods of transportation; and the "communications team" relays all data and recommendations to mission control as the team handles this crisis. During the simulation students communicate synchronously with a professional educator to inventory and move supplies and personnel located at different areas of the lunar habitation to ensure the safest outcomes possible. Students' decisions are based on the collection of numerous sources of quantitative data.

The field-based exploration builds on students' experiences working in cooperative teams to engage in a problem-based exploration involving a moon mission and a project-based exploration of rocketry. During the "moon mission," students "launch" into space where they perform various data collecting and analysis activities, experiments, and troubleshoot mechanical mishaps on board a space station. Meanwhile, other students work cooperatively in "Mission Control" to monitor and guide the astronauts' activities to successfully complete their mission. Both the "Space Station" and "Mission Control" are designed to look like authentic space craft and control centers responsible for managing aerospace operations and vehicle flights. Halfway through the mission, participants switch roles so everyone can experience both "Mission Control" and the "Space Station." During the project-based exploration of rocket science, students receive a brief tutorial concerning the structure and function

| Subscales | N (Valid Cases) | N (Items) | Cronbach's Alpha (□) |
|---|---|---|---|
| Interests in learning STEM | 181 | 11 | .86 |
| Perceptions regarding the usefulness of STEM | 181 | 7 | .80 |
| Intentions to persist in STEM | 182 | 9 | .89 |
| STEM self-efficacy | 173 | 8 | .84 |
| Perceptions of group work | 183 | 9 | .81 |

**Table 1. Reliability statistics for the four STEM subscales (interests, perceptions, intentions, and self-efficacy) and perceptions of group work.**

| | | Mean | | Variance | | Skew | | Kurtosis | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | n | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| Interests in STEM | 189 | 3.27 | 3.93 | 0.12 | 0.46 | 0.15 | -0.79 | -0.33 | 0.94 |
| Perceptions about STEM | 188 | 3.08 | 3.97 | 0.09 | 0.49 | -0.11 | -0.90 | -0.20 | 1.80 |
| Intentions to persist | 188 | 3.22 | 3.67 | 0.18 | 0.61 | -0.22 | -0.36 | 1.12 | 0.85 |
| STEM self-efficacy | 188 | 3.98 | 4.18 | 0.29 | 0.39 | -0.56 | -0.80 | 1.11 | 1.25 |
| Perceptions of group work | 186 | 3.31 | 3.96 | 0.25 | 0.40 | -0.52 | -0.70 | 1.46 | 1.77 |

**Table 2. Descriptive statistics for STEM subscale scores and perceptions of group work.**

| Variable | Mean | N | Std Dev. |
|---|---|---|---|
| $t_1$ STEM Score | 3.39 | 189 | 0.26 |
| $t_2$ STEM Score | 3.94 | 189 | 0.61 |

**Table 3. The significant mean difference in combined STEM subscale scores from pre to posttest.**

| Source | df | SS | MS | F | p | $\eta_p^2$ | Obs. Power |
|---|---|---|---|---|---|---|---|
| Between | | | | | | | |
| Pre-Post (A) | 1 | 113.69 | 113.69 | 130.38 | .00 | 0.26 | 1.00 |
| Error | 375 | 326.93 | 0.87 | | | | |
| Within | | | | | | | |
| Subscales (B) | 3 | 92.87 | 30.96 | 211.74 | .00 | 0.36 | 1.00 |
| A X B | 3 | 24.32 | 8.11 | 55.46 | .00 | 0.13 | 1.00 |
| Error | 1125 | 164.47 | 0.15 | | | | |

**Table 4. Repeated measures ANOVA with partial ETA and observed power values among the four STEM subscales (Factor A), between time 1 and time 2 measurements (Factor B), and for their interaction (AxB).**

of rocket parts, and work cooperatively using math, writing, design engineering, and interpersonal skills to design, construct, test and launch paper rockets.

### Data Collection

Our primary data sources include a modified attitudinal survey (Simpson-Troost Attitude Questionnaire [STAQ], 1982) and modified perceptions of collaboration survey (Hockings, De Angelis, & Frey, 2008) (See Appendix A). On the surveys, students indicate to which extent they agree or disagree with STEM attitudinal and perceptions of collaboration questions according to a 5-point Lickert response scale. The surveys were administered before students experienced the STEM program. The reliability for STAQ was reported as high, between 0.7 and 0.81 (Owen et al., 2008).

### Research Variables and Analysis

Five mean STEM subscale scores were calculated for each individual participating in this study. These five STEM subscale scores were: students' interest in STEM, students' perceptions about STEM, students' intentions to persist in STEM, students' STEM self-efficacy, and students' experiences in group activities. Lastly, the broad and generalized attitudinal questions of the original survey were further subdivided by three independent researchers into specific constructs being students' interest in STEM, students' perceptions about STEM, students' intentions to persist in STEM, and students' STEM self-efficacy.

The five subscales were reliable measures (Table 1 and Appendix B). The questions for each STEM subscale and the perceptions of group work subscale had "good" to "excellent" internal consistency ($0.7 \leq \alpha < 0.9$ [good]; $\alpha \geq 0.9$ [Excellent]); thus, substantiating the reliability of the assessment tool (Cronbach, 1951).

The variable *students' interest in STEM* focuses on the word "like". This subscale measures if students "like" STEM lessons and "like" to do STEM related activities in and out of the classroom, or if they find STEM lessons to be a waste of time. The variable *students' perceptions about STEM* measures individuals' beliefs about STEM and the usefulness for knowing and understanding STEM related concepts. This variable underpins students' perceived positive or negative outcomes for learning STEM concepts. The variable *students' intentions to persist* are comprised of questions targeting students' desire to continue studying STEM. *STEM self-efficacy* targets students' beliefs in their ability. One might consider self-efficacy similar to confidence to complete a task (task-specific self-efficacy) or confidence in a particular, more generalized domain (domain-specific self-efficacy). The variable *STEM self-efficacy* is a domain-specific self-efficacy measure of students' confidence and self-assurance in completing STEM related activities. The last subscale, students' experiences in group activities, contains several questions about an individual's perceptions of the helpfulness of group work to learn and understand content. These subscales, when combined, comprise the overall STEM score. Descriptive statistics for the subscales are provided in Table 2 showing that the skew and kurtosis falls within the acceptable range for normally distributed data.

The categorical independent variables for this study were gender (coded 1 and 2 for male and female) and group role. Group role consisted of three categories. On the survey, students are asked if they, while working within groups in class, tend to be group leaders (coded 3), group workers (coded 2), or group observers (coded 1). Though categorical, this measure can also be seen as an interval insomuch that from code 1 to code 3 individuals' level of engagement in group activities increases.

## Results

The results of this study are divided by research question. Each section begins with the research question, and specific results pertaining to the research question follows.

**Does an explicit approach to teaching science, technology, engineering, and mathematics have an effect on students' interests toward learning STEM, students' perceptions regarding the usefulness of STEM, students' intentions to persist in STEM, and STEM self-efficacy?**

There was a positive shift in overall mean STEM Score from before to after instruction (Table 3). Mean STEM Score significantly increased from 3.39 on the pre-test to 3.94 on the post-test; $F(1, 375) = 130.38$, $p < .01$ (Table 4). There was also a statistically significant difference among the subscales; $F(3, 1125) = 211.74$; $p < .01$, as well as a statistically significant interaction; $F(3, 1125) = 55.46$; $p < .01$ (Table 3).

A statistically significant difference among mean subscale scores (Factor B) was also found; $F(3, 1125) = 211.74$, $p < .01$. The significant difference resulted from overall mean differences among all four subscales, predominantly a result of students' heightened STEM self-efficacy scores. Additionally, the mean score for students' interests in STEM was significantly higher than students' perceptions regarding the usefulness of STEM, and students' perceptions regarding the usefulness of STEM was significantly higher than students' intentions to persist in

STEM (Table 5). The significant interaction (Factor AxB) resulted from the increase in students' perceptions regarding the usefulness of STEM in relation to the other subscale scores (Table 6).

| | Perceptions | Intentions | Self-Efficacy |
|---|---|---|---|
| Interests | 2.86** | 5.09** | -14.55** |
| Perceptions | | 2.82** | -17.19** |
| Intentions | | | -22.50** |

**p< .01

Table 5. Paired samples t-values (Column-Row) showing differences among the STEM subscales; Factor B (df =376).

| Variable | n | t1 | t2 | t-value |
|---|---|---|---|---|
| Interests toward learning STEM | 189 | 3.27 | 3.93 | -11.35** |
| Perceptions regarding the usefulness of STEM | 188 | 3.08 | 3.97 | -18.34** |
| Intentions to persist in STEM | 188 | 3.22 | 3.67 | -9.09** |
| STEM self-efficacy | 188 | 3.98 | 4.18 | -6.41** |

** p < .001

Table 6. Pre/Post means and paired t-values for the STEM subscales explaining the significant interaction; Factor A x B.

| Variable | N | $t_1$ | $t_2$ | t-value |
|---|---|---|---|---|
| Perceptions of Group Work | 186 | 3.31 | 3.96 | -13.04** |

** p < .001

Table 7. Pre/Post means and paired t-values for the STEM subscales and students' perceptions of group work (t1= time 1; t2= time 2).

| | | |
|---|---|---|
| I prefer to study with other people. | 3.74 | 3.93 |
| It helps me to study with students of other abilities. | 4.01 | 3.97 |
| If I can explain a problem to someone else, it helps me to learn the concept. | 4.12 | 3.96 |
| Working in groups makes me feel confident in my abilities. | 2.25 | 4.19 |
| Working in groups intimidates me.* | 1.95 | 3.69 |
| My problem solving skills improved from working in groups. | 3.83 | 4.00 |

*reverse coded (5 = strongly disagree)

Table 8. Mean differences in students' perceptions of group activities by item.

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Pre-Interests in STEM (1) | -.12 | -.16* | -.03 | -.13 | -.15* | -.20** | -.03 |
| Pre-Perceptions regarding the usefulness of STEM (2) | | .42** | .38** | .22** | .33** | .34** | .24** |
| Pre-Intentions to persist in STEM (3) | | | .49** | .44** | .43** | .62** | .39** |
| Pre-STEM self-efficacy (4) | | | | .51** | .50** | .62** | .75** |
| Post-Interests in STEM (5) | | | | | .70** | .70** | .64** |
| Post-Perceptions regarding the usefulness of STEM (6) | | | | | | .74** | .65** |
| Post-Intentions to persist in STEM (7) | | | | | | | .69** |
| Post-STEM self-efficacy (8) | | | | | | | 1 |

*p<.05 **p<.01

Table 9. Correlations among subscale variables

**Does an explicit approach to teaching the nature of science, technology, engineering, and mathematics have an effect on students' perceptions of group work?**

From pre-test to post-test, participants' mean score for perceptions of group work increased from 3.31 to 3.96; $t(186) = -13.04$, $p < .01$ (Table 7). The increase from pre to posttest was statistically significant.

The significant increase in mean score from time one to time two resulted from increased scores for items: "working in groups makes me feel confident in my abilities" and "working in groups intimidates me" (Table 8).

**Are students' STEM self-efficacy beliefs a significant predictor for students' intentions to persist in STEM?**

Correlations were calculated to determine the associations among the pre- and post- subscale variables (Table 9). The majority of the associations are significant with the exception of students' interests towards learning STEM before instruction.

The strongest associations among variables before instruction were found between students' STEM self-efficacy and students' intentions to persist ($r = 0.49$, $p<.01$) and students' perceptions regarding the usefulness of STEM and students' intentions to persist in STEM ($r = 0.42$, $p<.01$). Several strong associations were found between post-instruction variables. Significant associations were found between students' intentions to persist in STEM and students' perceptions regarding the usefulness of STEM ($r = 0.74$, $p<.01$), students' interests in STEM ($r = 0.70$, $p<.01$), and STEM self-efficacy ($r = 0.69$, $p<.01$).

The first simple linear regression analysis was performed using data prior to instruction. Prior to the regression, assumptions for linear regression were checked. Students' STEM self-efficacy beliefs significantly predicted students' intentions to persist in STEM; $F(1, 141) = 31.73$, $p< .01$. Prior to instruction, students' STEM self-efficacy beliefs uniquely predicted 17.9% of the variance in students' intentions to persist in STEM (Adj. $R^2 = 0.179$). Since both students' perceptions regarding the usefulness of STEM and STEM self-efficacy maintained moderate associations with students' intentions to persist, a multiple linear regression analysis was performed with students' perceptions regarding the usefulness of STEM and STEM self-efficacy as predictor variables and students' intentions to persist as the dependent variable. The regression model was significant; $F(2, 141)=23.97$, $p<.01$. Students' perceptions regarding the usefulness of STEM and STEM self-efficacy uniquely predicted 24.6% of the variance in students' intentions to persist in STEM.

Simple linear regression analysis techniques were performed for the post-instruction data. When comparing the regression models between pre- and post- instruction, students' STEM self-efficacy beliefs better predicted students' intentions to persist in STEM after instruction. The post-instruction regression model using STEM self-efficacy beliefs as a predictor for students' intentions to persist in STEM was significant; $F(1, 1141) = 92.30$, $p< .01$. Students STEM self-efficacy beliefs uniquely predicted 39.3% of the variance in students' intentions to persist in STEM (Adj. $R^2 = 0.393$). From pre-instruction to post-instruction, the association between STEM self-efficacy beliefs and students' intentions to persist in STEM increased. In addition to a stronger association, the amount of variance in students' intentions to persist in STEM predicted by STEM self-efficacy beliefs increased.

A second regression analysis was performed on the post-instruction data using students' interests in STEM, students' perceptions regarding the usefulness of STEM, and students' STEM self-efficacy as predictor variables for students' intentions to persist in STEM. A multiple regression analysis was utilized and the model was found to be significant; $F(3, 141) = 58.14$, $p<.01$. The three predictor variables explained 54.9% of the variance in students' intentions to persist. Of the three predictor variables, students' perceptions regarding the usefulness of STEM uniquely accounted for the greatest amount of variance in students' intentions to persist ($sr=0.29$, $pr= 0.40$).

**Are there statistically significant relationships among student subscale scores based on group experiences and group role?**

Group role, a categorical variable (0 =observer; 1 = worker; 2 = group leader), and students' experiences in group activities (subscale items in Table 8) significantly predicted STEM self-efficacy [$F(2, 199) = 37.05$, $p<.01$]. Group role and students' experiences in group activities predicted 26.4% of the variance in STEM self-efficacy (adj $R^2=0.264$). Students' experiences in group activities was a significant predictor of STEM self-efficacy, $t(199) = 5.39$, $p<.01$ and uniquely accounted for 10.63% of the variance in STEM self-efficacy ($sr = 0.33$). Group role was also a significant predictor of STEM self-efficacy, $t(199) = 5.91$, $p<.01$ and uniquely accounted for 14.98% of the variance in STEM self-efficacy ($sr = 0.36$). For the second regression model, group role and students' experiences in group activities significantly predicted 11.4 % (adj $R^2 = 0.114$) of the variance in students' intentions to persist in STEM related activities [$F(2, 199) = 13.98$, $p<.01$]. Students' experiences in group activities uniquely explained 6.25% ($sr = 0.25$) of the variance in students' intentions to persist, $t(199) = 3.77$, $p<.01$. Students' group role also significantly predicted intentions to persist, $t(199) = 3.16$, $p<.01$ and uniquely explained 4.16% of the variance in students' intentions to persist ($sr = 0.21$).

**Are there statistically important gender differences within the test population?**

To determine if there is a difference in the number of males and females who identify themselves as group leaders, group workers, or observers a chi-square for independence of variables was performed. For each category, expected frequencies were calculated dividing the row total by the grand total and then multiplying by the column total.

Table 10 identifies the observed and expected frequencies for each category. The chi-square ($X^2$) value for this analysis, which was found to be 1.34, was not statistically significant. There is no statistically significant difference between the number of men and women who claim to be group leaders, group workers, and group observers.

| | Group Leaders | Group Workers | Group Observers |
|---|---|---|---|
| Male | $f_o = 37$ $f_e = 41$ | $f_o = 40$ $f_e = 36$ | $f_o = 13$ $f_e = 13$ |
| Female | $f_o = 55$ $f_e = 51$ | $f_o = 43$ $f_e = 46$ | $f_o = 16$ $f_e = 16$ |

**Table 10. Observed and expected frequencies for men and women group leaders, workers, and observers.**

In addition to the chi-squared analysis, four independent t-tests were calculated to determine if there were differences between the STEM subscale scores by gender. No significant differences were found between male's and female's self-efficacy beliefs, $t(204)= 1.31$, $p>.01$, between male's and female's intentions to persist in STEM related activities, $t(204) =1.17$, $p>.05$, between male's and female's experiences in group activities, $t(201) = -.09$, $p>.05$, or between male's and female's interest in STEM $t(204) = .32$, $p>.05$.

## Discussion

To understand the nature of students' developing attitudes, and hence to improve understanding of how curriculum resources and project/problem based lessons influences students' knowledge and beliefs, this study investigated students engaged in a technology-rich STEM learning environment. This is the first of a series of studies aimed at better understanding STEM activities and students' attitudes, motivation, and perceptions of group work in middle school. The main findings show there were differences in students' STEM beliefs and attitudes before and after experiencing STEM curriculum. The greatest increase from pre-test to post-test was students' perceptions of the usefulness of STEM. In addition, students' perceptions of the usefulness of STEM explained the most variance in students' intentions to persist in STEM after instruction. A primary implication of this finding is that teachers must be explicit in explaining to students how STEM is interwoven in the various facets of life. Students' realization of the presence and impact of STEM in nearly every facet of their lives increases students' desire to persist in learning STEM content. The findings of this research study whereby students' perceptions of STEM and self-efficacy are the best predictors for students' intentions to persist in STEM is similar to Lent et al. (2005). Lent et al. (2005) explains that an individual's career related pursuits are dependent upon the individual's belief in their ability and the individual's perceptions of the career.

This study supports prior findings made by Britner and Pajares (2006), Catsambis (1994), Chen and Zimmerman (2007), Fouad and Smith (1996), and Pajares, Britner, and Valiante (2000) in that no significant differences (or correlation) in self-efficacy beliefs were found between middle school boys and girls. In this study, self-efficacy was not the best predictor for students' intentions to persist; rather, students' interest in STEM predicted more variance in intentions to persist than self-efficacy. Similarly, Fouad and Smith (1996) found in their series of model testing techniques, found self-efficacy to be a better determinant of outcome expectations rather than intentions to persist. Essentially, the evidence collected suggests that middle school students' self-efficacy is not the unpinning and most "direct" predictor for students' intentions to persist. Conversely, self-efficacy was found to be the best predictor for students' interest; and for Fouad and Smith's (1996) study, the best fitting model showed outcome expectations as a significant determinant for intentions. Another interesting finding from this study was that the middle school girls felt that understanding STEM would be helpful and useful; in fact, more so than boys. This finding may be the key as to why girls in this study maintained the same level of interest in STEM as boys. Catsambis (1994) explains the importance perceived usefulness has on girls' sustained interest. Unique to this study, there were no differences in the frequency of girls and boys who identified themselves as group leaders, group workers, or group observers. Additionally, there were no significant differences in sixth-grade boys and girls experiences in group activities.

The final purpose of this study, and one that has been less explored in the literature with possibly more significant implications, are the interrelationships among group role and students' experiences in group activities with self-efficacy, intentions to persist, perceptions of STEM and interests in STEM. Students who are less engaged in STEM group activities have lower self-efficacy beliefs, lower positive perceptions of STEM, less interest in STEM, and are less likely to persist in STEM related activities. By allowing students to self-select their role and remain in passive group roles, such as the group "worker" or "observer", can ultimately negatively affect self-efficacy beliefs and prevent the progression of positive interests and perceptions of STEM. One strong implication of this finding is that teachers can identify students as leaders, workers, and observers while working in groups based upon students' interactions and levels of engagement and infer which individuals have high levels of STEM self-efficacy beliefs, interests in STEM, positive perceptions of STEM, and are most likely to persist in STEM. By requiring students who normally do not take a leadership role to be the group "leader" in a STEM related activity may have a direct impact on positive self-efficacy beliefs, a greater interest in STEM, and an increased probability to persist in STEM. In this regard, students can benefit from learning more about roles and responsibilities in a group and the importance of collaboration in learning. Teaching students about roles and responsibilities is an opportunity to teach students about the interdependent nature of many real-life changing tasks that require students to draw on each other's strengths and weaknesses to accomplish a common goal. Teaching students the importance of collaboration and interdependence can have drastic impacts on their development of knowledge and better prepare them for the cooperative nature required by professionals solving problems in STEM related careers.

## Conclusions

Research on students' self-efficacy and perceptions of group work has the potential to restructure how teachers design activities and teach students about collaboration. This is the first study to investigate students' self-efficacy and perceptions of collaboration in relation to STEM related to gender. The main conclusions of the study are as follows:

1) An explicit approach to teaching science, technology, engineering, and mathematics significantly increases students' interests in STEM, students' perceptions regarding the usefulness of STEM, students' intentions to persist in STEM, and STEM self-efficacy.
2) An explicit approach to teaching the nature of science, technology, engineering, and mathematics increases students' perceptions of group work.
3) Students' STEM self-efficacy beliefs significantly predicted students' intentions to persist in STEM before and after instruction. In addition to students' STEM self-efficacy beliefs, students' perceptions regarding the usefulness of STEM also significantly predicted student' intentions to persist both before and after instruction.
4) There were statistically significant relationships among student subscale scores based on group experiences and group role. Group leaders have significantly greater STEM self-efficacy scores compared to group workers, and group workers have significantly greater STEM subscale scores for all variables compared to group observers.
5) There were no statistically significant differences among the STEM subscale scores by gender. Also, there was not a statistically significant difference in the frequency of men and women who reported as being group leaders, workers, or observes.

This study provides valuable insight into students' knowledge and attitudes at a specific grade level. As a result, this study is significant in that it objectively elucidates students' STEM related knowledge and beliefs, and perceptions about group work at a pivotal point in their academic careers. To develop more positive attitudes and desires to persist in STEM courses, majors, and careers, teachers must understand the knowledge and beliefs students bring to the classroom.

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# APPENDIX A: Survey containing all items

| Question Number | Question |
|---|---|
| 7 | I enjoy learning about science, technology, engineering, and mathematics (STEM). |
| 8 | Learning science, technology, engineering, and mathematics (STEM) is not important for my future success. |
| 9 | We do a lot of interesting activities in science class. |
| 10 | Most people should understand STEM because it affects their lives. |
| 11 | I will study STEM if I get into a college after high school. |
| 12 | I am sure I can do well on science tests. |
| 13 | I usually give up when I do not understand a STEM concept. |
| 14 | Science is one of the most interesting school subjects. |
| 15 | Teachers encourage me to understand concepts in science classes. |
| 16 | Science classes will help prepare me for college. |
| 17 | Science is easy for me. |
| 18 | My science teachers are very good teachers. |
| 19 | I will not pursue a STEM -related career in the future. |
| 20 | I like to watch TV programs about STEM. |
| 21 | I cannot understand STEM even if I try hard. |
| 22 | STEM is useful in solving everyday life problems. |
| 23 | I look forward to science activities in class. |
| 24 | A job in STEM would be boring. |
| 25 | I would like to learn more about STEM. |
| 26 | I really enjoy STEM lessons. |
| 27 | I will continue studying STEM after I leave high school. |
| 28 | My family encourages my interest in STEM. |
| 29 | I am confident that I can be successful in STEM. |
| 30 | We live in a better world because of STEM. |
| 31 | I would enjoy working in a STEM-related career. |
| 32 | I will miss studying STEM when I leave high school. |
| 33 | My friends like STEM. |
| 34 | Knowing STEM can help me make better choices about my health. |
| 35 | My family encourages me to have a STEM-related career. |
| 36 | I really like STEM. |
| 37 | If I could choose, I would not take any STEM courses in school. |
| 38 | Knowledge about STEM helps me protect the environment. |
| 39 | STEM-related work is only useful to scientists. |
| 40 | STEM will help me understand the world around me. |
| 41 | My friends do well in science. |
| 42 | If I work hard enough, I can learn difficult STEM concepts. |
| 43 | I will take additional STEM classes in the future. |

| | |
|---|---|
| 44 | STEM lessons are a waste of time. |
| 45 | Scientists do not have enough time for fun. |
| 46 | People with STEM-related careers have a normal family life. |
| 47 | I do not like STEM. |
| 48 | I like to visit science museums on the weekends and breaks from school. |
| 49 | I would like to know more about jobs using STEM. |
| 50 | I am motivated to pursue a career in STEM. |
| 51 | Discoveries in STEM do more harm than good. |
| 52 | It helps me to study with students that are better than I am. |
| 53 | I prefer to study with other people. |
| 54 | It helps me to study with students of other abilities. |
| 55 | I learn more when I see connections between several concepts. |
| 56 | If I can see a picture, I understand the concept better. |
| 57 | If I can explain a problem to someone else, it helps me to learn the concept. |
| 58 | Working in groups makes me feel confident in my abilities. |
| 59 | Working in groups intimidates me. |
| 60 | I have good problem solving skills. |
| 61 | I am good at solving problems. |
| 62 | My problem solving skills improved from working in groups. |
| 63 | The group activities improved my study habits. |
| 64 | In future science, technology, engineering and mathematics (STEM) classes, I am going to seek out a problem solving group for working problems. |
| 65 | I felt comfortable working through problems in our group. |
| 66 | In our group, I regularly explained problems to other students. |
| 67 | Interacting with other group members increased my understanding of the material. |
| 68 | In our group, I felt comfortable asking questions when I did not understand something. |
| 69 | Team work is often needed for solving really hard problems in science, technology, engineering, and mathematics (STEM). |
| 70 | When we talk about science, technology, engineering, and mathematics (STEM), I always have different opinions from my friends. |

## Appendix B.

Table 1. Items measuring students' interest in STEM

**Cronbach's Alpha = 0.86**

| Item Number | Question/Statement |
|---|---|
| 7 | I enjoy learning about science, technology, engineering, and mathematics (STEM). |
| 9 | We do a lot of interesting activities in science class. |
| 14 | Science is one of the most interesting school subjects. |
| 20 | I like to watch TV programs about STEM. |
| 26 | I really enjoy STEM lessons. |
| 32 | I will miss studying STEM when I leave high school. |
| 36 | I really like STEM. |
| 44 | STEM lessons are a waste of time. |
| 47 | I do not like STEM. |
| 48 | I like to visit science museums on the weekends and breaks from school. |
| 49 | I would like to know more about jobs using STEM. |

Table 2. Items measuring students' perceptions about STEM

**Cronbach's Alpha = 0.80**

| Item Number | Question/Statement |
|---|---|
| 10 | Most people should understand STEM because it affects their lives. |
| 22 | STEM is useful in solving everyday life problems. |
| 30 | We live in a better world because of STEM. |
| 34 | Knowing STEM can help me make better choices about my health. |
| 38 | Knowledge about STEM helps me protect the environment. |
| 40 | STEM will help me understand the world around me. |
| 51 | Discoveries in STEM do more harm than good. |

Table 3. Items measuring students' intentions to persist in STEM

**Cronbach's Alpha = 0.89**

| Item Number | Question/Statement |
|---|---|
| 8 | Learning science, technology, engineering, and mathematics (STEM) is not important for my future success. |
| 11 | I will study STEM if I get into a college after high school. |
| 19 | I will not pursue STEM-related career in the future. |
| 25 | I would like to learn more about STEM. |
| 27 | I will continue studying STEM after I leave high school. |
| 31 | I would enjoy working in a STEM-related career. |
| 37 | If I could choose, I would not take any STEM courses in school. |
| 43 | I will take additional STEM classes in the future. |
| 50 | I am motivated to pursue a career in STEM. |

Table 4. Items measuring students' STEM self-efficacy

**Cronbach's Alpha = 0.84**

| Item Number | Question/Statement |
|---|---|
| 12 | I am sure I can do well on science tests. |
| 13 | I usually give up when I do not understand a STEM concept. |
| 17 | Science is easy for me. |
| 21 | I cannot understand STEM even if I try hard. |
| 29 | I am confident that I can be successful in STEM. |
| 42 | If I work hard enough, I can learn difficult STEM concepts. |
| 60 | I have good problem solving skills. |
| 61 | I am good at solving problems. |

Table 5. Items measuring students' experiences in group activities

**Cronbach's Alpha = 0.81**

| Item Number | Question/Statement |
|---|---|
| 58 | Working in groups makes me feel confident in my abilities. |
| 59 | Working in groups intimidates me. |
| 62 | My problem solving skills improved from working in groups. |
| 63 | The group activities improved my study habits. |
| 64 | In future science, technology, engineering and mathematics (STEM) classes, I am going to seek out a problem solving group for working problems. |
| 65 | I felt comfortable working through problems in our group. |
| 66 | In our group, I regularly explained problems to other students. |
| 67 | Interacting with other group members increased my understanding of the material. |
| 68 | In our group, I felt comfortable asking questions when I did not understand something. |

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