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# Alignment of Hands-on STEM Engagement Activities with Positive STEM Dispositions in Secondary School Students

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**Abstract** This study examines positive dispositions reported by middle school and high school students participating in programs that feature STEM-related activities. Middle school students participating in school-to-home hands-on energy monitoring activities are compared to middle school and high school students in a different project taking part in activities such as an after-school robotics program. Both groups are compared and contrasted with a third group of high school students admitted at the eleventh grade to an academy of mathematics and science. All students were assessed using the same science, technology, engineering and mathematics (STEM) dispositions instrument. Findings indicate that the after-school group whose participants self-selected STEM engagement activities, and the self-selected academy of mathematics and science group, each had highly positive STEM dispositions comparable to those of STEM professionals, while a subset of the middle school whole-classroom energy monitoring group that reported high interest in STEM as a career, also possessed highly positive STEM dispositions comparable to the STEM Professionals group. The authors conclude that several different kinds of hands-on STEM engagement activities are likely to foster or maintain positive STEM dispositions at the middle school and high school levels, and that these highly positive levels of dispositions can be viewed as a target toward which projects seeking to interest mainstream secondary students in STEM majors in college and STEM careers, can hope to aspire. Gender findings regarding STEM dispositions are also reported for these groups.

**Keywords** STEM dispositions · Positive outcomes · Secondary school level

## Introduction

Science, technology, engineering and mathematics (STEM) are important for the global competitiveness of the USA (Banning and Folkestad 2012; Holden et al. 2010). The USA is increasingly reliant on the STEM workforce to maintain leadership in the world economy (Banning and Folkestad 2012). Improving the STEM workforce is a top priority for policy makers, practitioners and researchers with the need to recruit and retain more students to work in STEM-related fields (Heilbronner 2011), compete with the global competition and most importantly improve STEM literacy for all students (Bybee 2010). Research has shown that students have their dispositions toward disciplines like mathematics and science, shaped long before they begin college (George et al. 1992; Sadler et al. 2012). It is important to identify key components such as family influences, teachers and school curriculum, or out-of-school activities that lead some students to favor STEM disciplines and target STEM careers, in hopes of promoting broader participation in the STEM workforce of the future. One step in this process is to find individuals and/or groups who possess high dispositions, and then study their reasons for interest in STEM. This paper focuses on three

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secondary education programs that, based on measured STEM dispositions, can be shown to nurture and/or attract students with high interest in STEM content and careers.

## The Search for Positive STEM Dispositions

Previous research (Christensen et al. 2015; Knezek et al. 2015) by the authors indicated that teachers participating in STEM academy professional development activities possessed high STEM dispositions comparable to other STEM professionals providing data on the same instrument. These findings prompted the research team to gather new data from high school academy of mathematics and science students accepted into the STEM-intensive school because they possessed high knowledge and interest in STEM areas. It was hypothesized that the Texas Academy of Mathematics and Science (TAMS) students might possess dispositions comparable to STEM professionals rather than their age-level peers. The result shown in Fig. 1 confirmed that the high school students attending the academy indeed possessed highly positive STEM dispositions. The primary influences to which the academy students attributed their interest in STEM were:

1. Self-motivated/naturally inclined,
2. Parent/family member, or
3. High-quality/motivating teachers.

Additional details about the primary influences can be found in a separate publication (Christensen and Knezek 2013).

While the measured dispositions of various groups showed that as students advanced in years of school their dispositions toward STEM declined, the data from the academy students showed a different trend in these high school students. The "W" shape of Fig. 1 encouraged the research team to further expand the team's search, in the direction of meaningful and engaging STEM programs for mainstream secondary students who might also have the

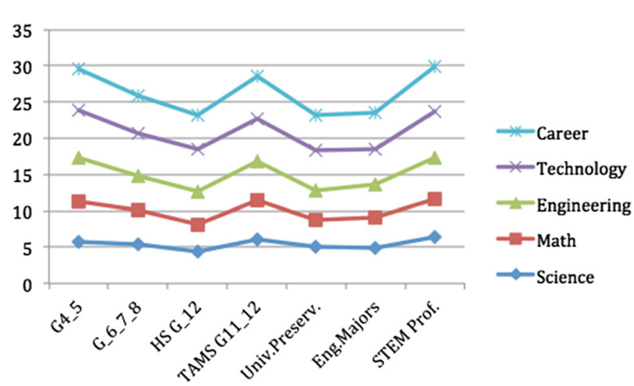


**Fig. 1** Cumulative STEM dispositions of seven survey groups

desired positive dispositions toward STEM, in order to compare and contrast their positive influences with those of the mathematics and science academy students discussed in the previous section. The authors gathered data from another STEM-related program, the Communication, Science, Technology, Engineering and Mathematics (CSTEM) program, examining post-treatment data for middle and high school students in grades 6–12, in hopes that their attitudes might also be high. Findings from this exploration were positive and will be addressed in detail in the current paper.

Finally, the research team returned to its original focus, the Middle Schoolers Out to Save the World (MSOSW) project, which was completing its first year of scale-up project support by the US National Science Foundation, in order to determine if some subset of post-treatment middle school students in the MSOSW project matched: (a) the STEM disposition attributes of mathematics and science academy students who had selected a STEM career path early in their secondary school education, and/or (b) the STEM dispositions of after-school STEM engagement program students who volunteered from among their peers to participate in teacher-led hands-on STEM activities. The outcomes from the MSOSW comparison segment of the study, as well as possible implications for STEM education programs nationwide, will also be detailed in the sections that follow.

## Research Questions

Three research questions guided this study:

1. How positive are end-of-year (post-treatment) dispositions of middle school students participating in hands-on STEM engagement activities toward STEM content areas and careers?
2. How do the STEM dispositions of students involved in meaningful, engaging, active learning STEM programs compare to:
   a. age-equivalent peers,
   b. academy of mathematics and science students, and
   c. STEM professionals?
3. To what extent do student STEM dispositions vary by type of activity involvement or by gender?

## Review of the Literature

Student attitudes toward STEM are important factors influencing student motivation to learn STEM subjects and to pursue a STEM career (Maltese and Tai 2011). Students begin losing interest in science as early as elementary school (Baird and Penna 1992; Keeley 2009) and the impact is greater on females (Abell 2007; Davidson 1995; Lederman 1997). Upper elementary and middle school students are at a critical stage of developing attitudes and beliefs in their abilities to take part in STEM activities (Maltese and Tai 2011) as well as explore career options (Super 1969). Previous studies have found that students who have positive attitudes toward science at the middle school level are more likely to pursue a STEM career (Tai et al. 2006). Not only is it important that the STEM workforce is developed, but it is critical that our citizens become scientifically and technologically literate (Milner et al. 2012).

Many previous studies have addressed ways to improve STEM interest in students. In general, researchers have concluded that more students might be interested in learning science if opportunities were more personally relevant and provided more space to explore and develop who the students might want to be (Aschbacher et al. 2013). Student-centered active learning has been shown to improve long-term knowledge retention and deep understanding (Bonwell and Eison 1991; Gallagher 1997; Akinoglu and Tandogan 2007). The strategies used for active learning closely align with guidelines used by the National Research Council to develop the Next Generation Science Standards (NGSS). For example, one goal is to have students conceptualize concepts as opposed to memorizing facts. The NGSS standards are intended to teach the application of concepts to real-world contexts. When using the active learning approach, education becomes more personally meaningful and takes advantage of students' natural curiosity. This approach prepares students for the future by having students communicate, collaborate and try new approaches in finding solutions to real-world problems. Middle school is an appropriate age to develop an interest in science that will persist through secondary school, into college and beyond into a career. Providing authentic, active learning experiences contributes to the internalization of learning about science.

Active learning principles are rooted in Dewey's "learning by doing and experiencing" principle (Dewey 1938). Dewey advocated that a child's schoolwork should have meaning and be engaging as well as have connections to other disciplines and life experiences. In an active learning model, the learner takes more responsibility for his/her own learning under the guidance of a teacher. Characteristics that are included in active learning include:

- relevance to real-world applications
- authentic solving of real-world problems
- application of prior knowledge and/or experiences to solve new problems
- collaboration with others
- integration of subject matters (interdisciplinary) and
- self-directed learning.

Within this context, it is proposed that strategies promoting active learning be defined as instructional activities "involving students in doing things and thinking about what they are doing" (Bonwell and Eison 1991). Collectively, researchers have established the importance of active, engaged learning in creating learning that is deep and meaningful.

While there is a concern for both males and females entering STEM careers, a study of 6000 students completed in 2012 indicated that by the end of high school, the odds of being interested in a STEM career are 2.9 times higher for males than for females (Sadler et al. 2012). Women account for only 20 % of the bachelor's degrees in engineering, computer science and physics even though high school boys and girls perform equally well on mathematics and science courses (Nguyen and Ryan 2008; American Association of University Women 2010). Young women believe that science and technology are not relevant to their future career goals (Lent et al. 2005). Research shows that girls start losing interest in mathematics and science during middle school (United States Department of Education 2006) and are more interested in careers where they can make a difference in the world helping others (Ceci et al. 2009). Girls tend to prefer to learn in a more social context and need to see connections between school assignments and the real world (Heemskerk et al. 2005).

A study conducted by the Girl Scouts of America compared females interested in STEM fields to those who were not interested in STEM fields. The researchers (Modi et al. 2012) found that those who were interested in STEM fields were higher achievers, betters students, had stronger support systems and had exposure to STEM fields. Other factors that have been shown to influence females' perceptions of pursuing a career in STEM are stereotypes regarding performance in mathematics and science areas (Walton and Spencer 2009; Nguyen and Ryan 2008), social and cultural cues that discourage girls (Bisland et al. 2011), as well as a lack of confidence in the ability to persevere through difficult material (Dweck 2006; Halverson 2011).

Thus programs that are aimed at promoting interest in STEM should strive to include real-world connections in an active learning environment to support the learning needs of both males and females. This paper features programs whose participants have engaged in active learning environments and whose dispositions can be shown to be positive toward STEM.

## Methods and Instrumentation

### Instrumentation

The STEM Semantics Survey was used to assess dispositions for each of the programs discussed in this paper. The STEM Semantics Survey was adapted from Knezek and Christensen's (1998) Teacher's Attitudes Toward Information Technology Questionnaire (TAT) derived from earlier Semantic Differential research by Zaichkowsky (1985). The five most consistent adjective pairs of the ten used on the TAT were incorporated as descriptors for target statements reflecting perceptions of Science, Math, Engineering and Technology. A fifth scale representing interest in a career in STEM was also created. Internal consistency reliabilities for the five scales of the STEM Semantics Survey typically range from $\alpha = .90$ to .94 for students such as those participating in this study (Tyler-Wood et al. 2010). These reliability estimates fall in the range of "excellent" according to guidelines provided by DeVellis (1991). The five scales on the STEM Semantics Survey each have five items that are presented through semantic adjective pairs (boring: interesting; exciting: unexciting; and so forth) serving as anchors on a seven-point rating scale. Because each scale is counterbalanced with the same adjective pairs (in random order) and anchored with the same minimum and maximum ratings, a "cumulative STEM disposition" of the type represented in the layer graphs in this paper (a cumulative score summed across all STEM areas) can be produced. The STEM Semantics Survey has been used across many projects throughout the USA allowing comparisons to be made among sets of data.

### Participants

Participants in this study were from three groups of students in secondary school settings. Each group will be more fully described in the sections that follow.

*Middle Schoolers Out to Save the World (MSOSW)*

MSOSW is an Innovative Technology Experiences for Students and Teachers (ITEST) project funded by the US National Science Foundation beginning in 2008 with a scale-up phase beginning in 2013 and continuing through 2017. The purpose of ITEST is to facilitate research on factors that encourage early interest among students in STEM content and careers. As of 2013, classrooms in eight US states were participating in the MSOSW project directed by researchers at the University of North Texas (UNT). In the MSOSW project, teachers receive training in pedagogical as well as content knowledge required to teach the unit to their students. After training, the teachers guide their students in monitoring energy used by home and school appliances, in order to assess the amount of standby power consumed by the devices when they are not performing any useful functions. Students spend 3 weeks studying energy content, the impact of climate changes, measuring standby power at home and in school and creating what-if scenarios of how students and families can individually and collectively make a difference in the amount of $CO_2$ that is produced by their community.

During the 2013–2014 academic year, data were gathered from 914 MSOSW treatment and comparison middle school students during the posttest phase of the project year, in 2014. For the current study, data from 115 of these 914 middle school students who completed project activities under the supervision of their teachers during the first year of the scale-up phase of the MSOSW project, serve as the primary comparison group for the two other contrast groups whose data sets also represent post-treatment disposition measures. Students completed the surveys online at the end of the 2014 academic year, in April–June.

*Communication, Science, Technology, Engineering and Mathematics (CSTEM) Program*

The CSTEM program is an after-school program that includes a year-end culminating competition that engages students in multi-age groups to collaboratively solve six challenges that are designed by industry professionals and national standards-aligned project-based learning activities, thus demonstrating the impact of teacher training on student learning and student performance in a STEM competition environment. The six challenges revolve around competitions in the creation and development of remote-controlled robots, geoscience, creative writing, sculpture, film and photography. The students are required to participate in all challenge categories, providing them with an integrated STEM learning experience. The teachers are required to participate in 24 contact hours of professional development. The program kicks-off each fall and culminates in the spring with a competition.

Survey responses were gathered from 80 middle school students in grades 6–8 and 64 high school students during the CSTEM end-of-year event in May 2014. A temporary laboratory of approximately 30 netbook computers with wireless internet connections to the server enabled online administration of the surveys to these students.

*Texas Academy of Mathematics and Science (TAMS)*

The TAMS is a residential program housed at the UNT for high school juniors and seniors who are high achievers and interested in mathematics and science. TAMS is a two-year program in which students complete 2 years of college courses in lieu of their final 2 years in high school. Because these students are high achievers in the areas of STEM, they provide a unique resource for learning how educational environments might interest more students in STEM careers.

Data were gathered from 360 Year 1 (11th grade) and Year 2 (12th grade) students attending TAMS in the spring of 2014. Surveys were completed via paper and pencil forms during a year-end seminar for the 2013–2014 academic school year.

*Summary of Primary Comparison Groups*

While these three programs all have similar goals of encouraging students to be interested in STEM careers, they differ in their approaches. The MSOSW project students experience the authentic, hands-on STEM program through their middle school classroom teachers. The teachers have been trained to teach the standby energy unit by attending a summer training institute. Each student in the classroom of the program teachers is included in the program. The CSTEM program is an after-school, year-long set of carefully designed activities that culminate in an end-of-year competition for students from elementary, middle and high school. TAMS' students were required to apply and be at an advanced level of achievement in mathematics and science to be admitted to the program. TAMS' students interest in STEM is expected to be highly positive but still worthy of study to determine the influences and experiences that created student interests in STEM. TAMS' data also provide a comparison for the CSTEM high school students.

*Additional Comparison Data Sets*

Additional data were presented for comparisons in the earlier portions of this paper (see Fig. 1). These data were gathered from 11th to 12th graders attending a college fair, students in university preservice courses, fourth and fifth graders participating in a digital fabrication project, engineering majors at a job fair, and STEM professionals including NSF principal investigators, STEM education faculty members and MSOSW project teachers from various locations in the USA. These additional comparison groups were used to contextualize the data sets featured in this paper.

### Data Analysis and Presentation of Findings

Descriptive statistics, analysis of variance (ANOVA) and effect size (ES) computations (Cohen's $d$) were used to examine the data. General group mean trends were represented graphically whenever possible. ANOVA was used for inferential statistics questions such as whether or not STEM dispositions differed by gender. Effect size estimates (Cohen 1988) were used to assess the magnitude (as opposed to rarity by chance) of differences found.

## Results

### Research Questions 1 and 2

Research questions 1 and 2 focused on whether students who had participated in the hands-on STEM engagement activities possessed positive STEM dispositions (question 1), and whether these dispositions were more like their age-equivalent peers or more like those of academy of mathematics and science students who enrolled because of their interest in STEM (question 2). These research questions will be addressed by comparing and contrasting the STEM dispositions of students in the MSOSW, CSTEM and TAMS programs.

*MSOSW versus CSTEM Middle School Students*

As shown in Table 1, CSTEM students were found to be highly positive in their STEM dispositions, higher than MSOSW student dispositions at the posttest time for project participation. The average effect size (ES) between MSOSW and CSTEM middle school students, across five dispositions, was Cohen's $d = .51$, which would be considered moderate (Cohen 1988) and educationally meaningful (beyond ES = .3) according to commonly accepted guidelines (Bialo and Sivin-Kachala 1996).

As shown in Table 2, when MSOSW students were separated into those who indicated a high interest in STEM as a career (>5.5 on 1–7 scale, 74th percentile = approximately top quarter, $n = 36$), the disaggregated *high STEM career interest* group of the MSOSW classroom-based treatment students became more similar in their dispositions to the students who self-selected because of strong STEM interest to participate in the CSTEM after-school program. Of the 36 MSOSW students in this *high STEM career interest* category, 32 chose STEM as their intended career on the demographic career intention variable.[1] As shown in the ES columns of Table 2, the average magnitude of difference between high STEM and low STEM career interest for MSOSW students was ES = 1.59 (.88 excluding the STEM Career measure) while the average

[1] An analysis of variance (ANOVA) for career intention of MSOSW students who stated intention for a STEM career versus those who did not, revealed no significant differences ($p < .05$) in any of the five STEM disposition measures.

**Table 1** Comparison of STEM dispositions for middle school students in two programs

| | MSOSW post 2014 | | | C-STEM 6–8th grade | | | Comparison | |
|---|---|---|---|---|---|---|---|---|
| | *N* | Mean | SD | *N* | Mean | SD | *p* | ES |
| STEM science | 115 | 4.87 | 1.42 | 80 | 5.75 | 1.39 | .0001 | .63 |
| STEM mathematics | 112 | 4.48 | 1.56 | 80 | 5.23 | 1.58 | .0013 | .48 |
| STEM engineering | 113 | 4.50 | 1.67 | 80 | 5.41 | 1.47 | .0001 | .58 |
| STEM technology | 113 | 5.57 | 1.30 | 80 | 5.68 | 1.34 | .57 | .08 |
| STEM career | 114 | 4.68 | 1.52 | 80 | 5.75 | 1.26 | .0001 | .77 |

**Table 2** Contrasting top quarter of MSOSW students with lowest quarter and C-STEM participants

| | Top quarter | | | Bottom quarter | | | ES top versus bottom | ES top versus CSTEM MS | ES top versus STEM Prof. |
|---|---|---|---|---|---|---|---|---|---|
| | *N* | Mean | SD | *N* | Mean | SD | | | |
| STEM science | 36 | 6.05 | .99 | 27 | 4.00 | 1.28 | 1.23 | .25 | .29 |
| STEM mathematics | 36 | 4.95 | 1.62 | 26 | 4.04 | 1.78 | .53 | −.17 | .22 |
| STEM engineering | 35 | 5.59 | 1.44 | 27 | 3.60 | 1.92 | 1.17 | .12 | −.01 |
| STEM technology | 36 | 6.04 | 1.06 | 27 | 5.25 | 1.58 | .59 | .30 | −.36 |
| STEM career | 36 | 6.34 | .55 | 27 | 2.67 | 1.04 | 4.41 | .61 | −.13 |

magnitude of the difference between MSOSW high STEM career interest and CSTEM students was ES = .22 (.13 excluding STEM Career). The former would be considered large and educationally meaningful, while the latter would be considered small and not educationally meaningful according to published guidelines (Cohen 1988; Bialo and Sivin-Kachala 1996).[2] The upper quarter of the whole-classroom MSOSW students is very similar in their STEM dispositions to the self-selected, after-school, CSTEM project students.

### *CSTEM versus Math/Science Academy High School Students*

As shown in Table 3, the CSTEM high school students were more positive in their dispositions toward engineering and technology than the TAMS students and lower in their dispositions toward mathematics and science. The average ES was .13 which would be considered small according to the guidelines provided by Cohen (1988) and not educationally meaningful according to commonly accepted guidelines (Bialo and Sivin-Kachala 1996).[3] The educationally meaningful ESs (ES > .3) for science and mathematics, as well as STEM career, serve to re-validate the STEM Semantics Survey instrument, in that these findings verify that students choosing to attend an academy of mathematics and science early university admissions program possess especially high dispositions toward mathematics and science, and have a strong intention of pursing STEM as a career.

As graphically displayed in Fig. 2, CSTEM middle school students were a bit lower than but comparable to the TAMS grades 11 and 12 students on measured dispositions. The CSTEM middle school students were more positive than the aggregate MSOSW whole-classroom treatment middle school group of students on all five dispositions, but the self-selected CSTEM students had dispositions very similar to the subset of MSOSW students who indicated high interest in STEM as a career.

Thus the answer to research question 1 is that indeed middle school students participating in hands-on STEM engagement activities possess positive dispositions toward STEM content and careers. Evidence is accruing that whole class hands-on STEM engagement activities produce greater gains in content knowledge and more positive STEM dispositions than those that are found in comparison groups (Knezek et al. 2013; Knezek et al. 2014).

The answer to research question 2 is that the STEM dispositions for middle school students participating in hands-on STEM engagement activities are more like those of academy students and STEM professionals than their typical age-equivalent peers. In particular, CSTEM student dispositions are more like those of the academy students (and STEM professionals) than they are like those of the

[2] Similarly, the top quarter of the MSOSW students is more like the STEM Professionals than the bottom quarter of the MSOSW students (see Table 2).

[3] The profile of the dispositions of TAMS students is even more similar to STEM Professionals than CSTEM high school students (see Fig. 2).

**Table 3** Comparison of STEM dispositions for high school students in two programs

| | TAMS (grade 11–12) | | | C-STEM (grade 9–12) | | | Comparison | |
|---|---|---|---|---|---|---|---|---|
| | *N* | Mean | SD | *N* | Mean | SD | *p* | ES |
| STEM science | 360 | 6.09 | 1.03 | 64 | 5.53 | 1.44 | .0002 | .85 |
| STEM mathematics | 360 | 5.40 | 1.35 | 64 | 4.87 | 1.62 | .0053 | .36 |
| STEM engineering | 359 | 5.27 | 1.55 | 64 | 5.47 | 1.43 | .337 | −.13 |
| STEM technology | 359 | 5.85 | 1.29 | 64 | 5.89 | 1.43 | .82 | −.03 |
| STEM career | 359 | 6.15 | 1.10 | 64 | 5.58 | 1.45 | .0003 | .44 |

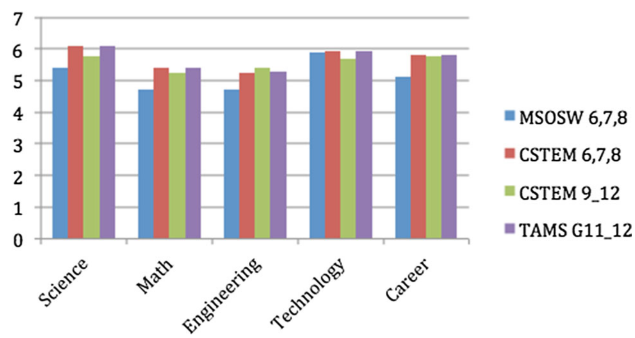


**Fig. 2** STEM Dispositions of CSTEM Grades 6–8 and 9–12 in Context of MSOSW 6–8 and Academy of Math and Science Grades 11–12

mainstream middle school students in the MSOSW project, the majority of whom do not report a high interest in STEM as a career. However, the MSOSW project participants who do report a high interest (top quarter) in STEM as a career also have STEM dispositions similar to CSTEM student dispositions, as well as similar to academy of mathematics and science students and STEM Professionals.

## Research Question 3

Research question 3 addressed comparisons among disaggregated data subgroups specifically focusing on type of activity and gender of the participants. The findings for the subgroups are described in the following section.

### *Type of Activity*

Participation in STEM-related activities varies by type of program. In this paper, researchers examined dispositions of students based on whether the students selected to participate in the program or whether they were in a classroom in which the activities took place.

The MSOSW project is a school-based program in which many of the activities such as monitoring energy for appliances are completed at home, under parent supervision. The program takes place in typical classrooms across the USA. As shown in Table 4, a subset of the MSOSW treatment students was selected for comparison with CSTEM, based on their high interest in STEM career. It was hypothesized that those in the top quarter of the MSOSW whole-classroom inclusion group, based on interest in a STEM career, would be more similar to the CSTEM students who had selected to attend an optional STEM program because of high interest. As shown in Table 4, the MSOSW high STEM career interest students were slightly more positive toward Science and slightly less positive toward Mathematics than their CSTEM peers, but only in the area of STEM career interest was the difference between the two groups significant ($p < .05$).

CSTEM students chose to participate in an after-school program that included a culminating competition event. While the CSTEM students were required to participate in all of the content areas of the program during the year, they were allowed to select a team for the end-of-year competition from: (1) robotics, (2) photography, (3) mural team, (4) sculpture team, (5) filmmaking team, (6) geoscience team or (7) other. Thus, the answer to the first part of research question 3 is yes, dispositions do vary based on type of activity selected.

The TAMS students are unique in that they had self-selected attendance in a residential college-based program focused on mathematics and science in order to complete their high school degree. Some prior experiences or influences likely impacted the TAMS students' decisions to attend a college-level academy for the last two of their high school years. Previous research has shown that these students attribute their interest in STEM areas to self-motivation, family members and motivating teachers (Christensen and Knezek 2013).

### *Gender Findings*

Comparisons of males versus females for each of the three groups indicated there were differences ($p < .05$) by gender for MSOSW middle school students, TAMS academy students and CSTEM middle school participants, but not for the CSTEM high school participants.

For Middle Schoolers Out to Save the World (MSOSW) students, females had less positive STEM dispositions ($p < .05$, not shown) than males in all five STEM measures prior to the project treatment. By the end of the treatment

**Table 4** Comparison of STEM dispositions for students with high STEM career dispositions

| | Top quarter MSOSW post 2014 | | | C-STEM 6–8th grade | | | Sig. | ES |
|---|---|---|---|---|---|---|---|---|
| | *N* | Mean | SD | *N* | Mean | SD | | |
| STEM science | 36 | 6.05 | .99 | 80 | 5.75 | 1.39 | .246 | .25 |
| STEM mathematics | 36 | 4.95 | 1.62 | 80 | 5.23 | 1.58 | .383 | −.17 |
| STEM engineering | 35 | 5.59 | 1.44 | 80 | 5.41 | 1.47 | .545 | .12 |
| STEM technology | 36 | 6.04 | 1.06 | 80 | 5.68 | 1.34 | .158 | .30 |
| STEM career | 36 | 6.34 | .55 | 80 | 5.75 | 1.26 | .008 | .61 |

**Table 5** STEM dispositions by gender for MSOSW middle school treatment students

| | *N* | Mean | SD | Sig. | ES |
|---|---|---|---|---|---|
| *STEM science* | | | | | |
| Male | 65 | 4.79 | 1.49 | | |
| Female | 65 | 4.79 | 1.45 | | |
| Total | 130 | 4.79 | 1.47 | .995 | .00 |
| *STEM mathematics* | | | | | |
| Male | 63 | 4.59 | 1.51 | | |
| Female | 64 | 4.39 | 1.66 | | |
| Total | 127 | 4.49 | 1.58 | .475 | .13 |
| *STEM engineering* | | | | | |
| Male | 64 | 5.11 | 1.42 | | |
| Female | 64 | 4.05 | 1.68 | | |
| Total | 128 | 4.58 | 1.64 | .000 | .68 |
| *STEM technology* | | | | | |
| Male | 62 | 5.80 | 1.41 | | |
| Female | 65 | 5.43 | 1.16 | | |
| Total | 127 | 5.61 | 1.30 | .104 | .29 |
| *STEM career* | | | | | |
| Male | 64 | 4.77 | 1.47 | | |
| Female | 65 | 4.71 | 1.54 | | |
| Total | 129 | 4.74 | 1.50 | .827 | .04 |

**Table 6** STEM dispositions for CSTEM middle school students by gender

| | *N* | Mean | SD | Sig. | ES |
|---|---|---|---|---|---|
| *STEM science* | | | | | |
| Male | 33 | 5.78 | 1.31 | | |
| Female | 47 | 5.43 | 1.43 | | |
| Total | 80 | 5.57 | 1.39 | .275 | .26 |
| *STEM mathematics* | | | | | |
| Male | 33 | 5.48 | 1.47 | | |
| Female | 47 | 5.06 | 1.64 | | |
| Total | 80 | 5.23 | 1.58 | .245 | .27 |
| *STEM engineering* | | | | | |
| Male | 33 | 5.66 | 1.43 | | |
| Female | 47 | 5.23 | 1.48 | | |
| Total | 80 | 5.41 | 1.47 | .203 | .30 |
| *STEM technology* | | | | | |
| Male | 33 | 6.05 | 1.25 | | |
| Female | 47 | 5.42 | 1.35 | | |
| Total | 80 | 5.68 | 1.34 | .038 | .48 |
| *STEM career* | | | | | |
| Male | 33 | 5.85 | 1.18 | | |
| Female | 47 | 5.68 | 1.33 | | |
| Total | 80 | 5.75 | 1.26 | .548 | .11 |

year, the only measure in which males remained significantly higher ($p < .05$) than females was engineering (Cohen's $d$ ES = .68). As shown in Table 5, ESs for the other dispositions were close to zero with the exception of technology, where males tended to be higher than females (ES = .29).

For CSTEM participants, regarding differences based on gender at the middle school level, male dispositions were higher on all five STEM measures, and significantly higher ($p < .05$) on the Technology measure, as shown in Table 6. ESs ranged from .11 to .48 with male dispositions in every area except *STEM Career* approaching the range that can be considered educationally meaningful (Bialo and Sivin-Kachala 1996). As shown in Table 7, no significant ($p < .05$) differences by gender were found for any of the five major STEM dispositions measured for high school students in the CSTEM program.

For the TAMS students, the males were significantly ($p < .05$) higher in STEM engineering (ES = .41), mathematics (ES = .41) and technology (ES = .49). For science and STEM career, no significant differences ($p < .05$) were found and the ESs were close to zero. The results of ANOVA and ES calculations are listed in Table 8.

Viewing these findings across projects, we conclude that the answer to the second part of research question 3 regarding gender differences is complex. There is evidence of gender differences in STEM dispositions within all three programs in varying degrees. At the middle school level,

Table 7 STEM dispositions for CSTEM high school students by gender

| | *N* | Mean | SD | Sig. | ES |
|---|---|---|---|---|---|
| *STEM science* | | | | | |
| Male | 37 | 5.52 | 1.46 | | |
| Female | 27 | 5.55 | 1.44 | | |
| Total | 64 | 5.53 | 1.44 | .937 | −.02 |
| *STEM mathematics* | | | | | |
| Male | 37 | 5.06 | 1.70 | | |
| Female | 27 | 4.59 | 1.50 | | |
| Total | 64 | 4.87 | 1.62 | .253 | .29 |
| *STEM engineering* | | | | | |
| Male | 37 | 5.43 | 1.49 | | |
| Female | 27 | 5.53 | 1.37 | | |
| Total | 64 | 5.47 | 1.43 | .787 | −.07 |
| *STEM technology* | | | | | |
| Male | 37 | 5.87 | 1.56 | | |
| Female | 27 | 5.92 | 1.25 | | |
| Total | 64 | 5.89 | 1.43 | .895 | −.04 |
| *STEM career* | | | | | |
| Male | 37 | 5.59 | 1.51 | | |
| Female | 27 | 5.56 | 1.39 | | |
| Total | 64 | 5.58 | 1.45 | .944 | .02 |

Table 8 Comparisons of males and females on STEM indicators at posttest (Spring 2014)

| | *N* | Mean | SD | Sig. | ES |
|---|---|---|---|---|---|
| *STEM science* | | | | | |
| Male | 180 | 6.04 | 1.22 | | |
| Female | 159 | 6.10 | 1.02 | | |
| Total | 339 | 6.07 | 1.13 | .624 | −.05 |
| *STEM mathematics* | | | | | |
| Male | 179 | 5.71 | 1.23 | | |
| Female | 159 | 5.17 | 1.42 | | |
| Total | 338 | 5.46 | 1.34 | .0005 | .41 |
| *STEM engineering* | | | | | |
| Male | 179 | 5.63 | 1.34 | | |
| Female | 158 | 5.05 | 1.48 | | |
| Total | 337 | 5.36 | 1.44 | .0005 | .41 |
| *STEM technology* | | | | | |
| Male | 180 | 6.25 | 1.01 | | |
| Female | 157 | 5.72 | 1.16 | | |
| Total | 337 | 6.01 | 1.11 | .0005 | .49 |
| *STEM career* | | | | | |
| Male | 180 | 6.08 | 1.20 | | |
| Female | 158 | 6.00 | 1.17 | | |
| Total | 338 | 6.04 | 1.18 | .578 | .07 |

females in the typical school environment appear to have dispositions lower than males in all measured dispositions. In the MSOSW project, female participants were no longer significantly lower than males at the end of the project year, with the exception of dispositions toward technology. Similarly, for CSTEM middle school students assessed at the end of the project year, males were higher but only significantly higher ($p < .05$) with respect to technology. Therefore, at the middle school level, the authors conclude that there are identifiable gender differences between males and females with respect to STEM dispositions.

Differences between males and females are less apparent at the high school level. In fact, there is evidence that females are close to parity at the high school level. As shown in Table 8, females participating in the CSTEM program are slightly higher on science, engineering and technology while males are somewhat higher on Mathematics and STEM career. However, none of these differences would be rare by chance. For TAMS students, there is little difference in dispositions for Science and STEM career. However, indications from a separate measure focusing on having a career that makes a difference in the world, are that TAMS females may be more positive in this area (Christensen et al. 2014). Additionally, in the area of dispositions toward technology, there is evidence that for certain kinds of technologies, females have more positive dispositions than males at the high school level (Knezek and Christensen 2009). Gender preferences, rather than gender differences, may be a better term at the high school level. Therefore, the answer to the second part of research question 3 regarding gender differences is less conclusive at the high school level.

## Discussion

As shown in Table 3, when comparing the two high school student groups, the academy students were higher in their measured dispositions toward mathematics, science and STEM career. This might be expected because the academy attended by the eleventh and twelfth grade students focuses on accepting students with strong interest in mathematics and/or science. Similarly, the CSTEM high school students were higher than the academy students (though not significantly so) in the areas of engineering and technology. These higher dispositions for CSTEM students also reflect the major focus areas for the CSTEM program.

As shown in Tables 1 and 3, and graphically displayed in Fig. 2, the only disposition in which there were not extensive differences found among the student subgroups in this study was Semantic Perception of Technology. It may be that all students of the millennial generation have relatively high dispositions toward technology.

As shown in Table 4, the average ES for students who participated in robotics versus those who participated in the other competitions on semantic perception of engineering, was ES = .53. This is a moderate effect according to Cohen (1988) and definitely beyond the .3 cutoff for the point at which the magnitude of the differences become educationally meaningful (Bialo and Sivin-Kachala 1996). Perhaps these students picked robotics because they liked engineering, or maybe robotics caused them to like engineering. Future studies of the CSTEM program may be able to ascertain in which direction the influence occurred.

Many other findings in the CSTEM data emerged during the analysis and have prompted the research team to target areas for future research. One interesting outcome is that the CSTEM students who picked Mural Team appear to be very high in semantic perceptions of science (like those who picked Robotics), which is a strong argument for the current STEAM (science, technology, engineering, arts and mathematics) movement (Ghanbari 2014).

In this study, for the high school students in the CSTEM program, no significant ($p < .05$) differences by gender were found for any of the five major STEM dispositions measured. That is unlike most groups of students the researchers have surveyed. Most groups of students have some gender differences in the scales employed (Knezek et al. 2011; Christensen et al. 2014).

## Implications

The programs presented in this paper all promote active engagement of students in "doing science" rather than passively studying science from a textbook. This curriculum delivery choice is believed to be responsible for much of the consistency of behavior and intellect of high STEM disposition students. These findings are consistent with findings from previous studies. For example, The International Mathematics and Science Study (TIMSS) study found a consistent relationship between attitude and achievement (Beaton et al. 1996) while much of the research has concluded that attitude impacts behavior (Osborne et al. 2003). The classroom environment has been shown to be a significant factor related to attitude toward school science (Myers and Fouts 1992; Talton and Simpson 1987). Researchers who have studied reasons students might become disinterested in science have suggested that the type of science taught in school is somehow disconnected from the real world (Ebenezer and Zoller 1993; Sundberg et al. 1994). Science involves not only learning scientific ideas but also engaging in practices of inquiry (NRC 2012). School science should be more prospective rather than retrospective (Ebenezer and Zoller 1993; Sundberg et al. 1994). Using approaches that have the essential elements of active learning may help increase student interest in STEM careers.

## Conclusions and Future Study

The findings of this research study collectively imply that many kinds of hands-on, active learning, engaging STEM programs related to making things relevant to the real world may be effective in promoting (or retaining) positive interest in STEM content and careers. These findings are consistent with the literature regarding developing student interest in STEM by creating hands-on, relevant activities for students to pursue (Aschbacher et al. 2013). However, it is also clear from this study that not all activities are equal across ages or grade levels of students. For example, the high school CSTEM students in grades 11–12 appear to be less positive in most areas than the CSTEM middle school students, so probably the trend to become less enthusiastic as age progresses is also present in this group of students, as has been found in prior studies (Dunn-Rankin et al. 1971; Christensen and Knezek 2001; Christensen et al. 2014; Potvin and Hasni 2014).

Program type, such as a school-based program in which every student is included and must participate in the program, versus a program in which a student self selects to participate due to interest in STEM, clearly impacts the measured levels of STEM dispositions. Probably, it is not realistic to expect every mainstream middle school student to be positively affected regarding their life's career by a single program activity that may span only a few weeks.

While gender differences appear to be more favorable toward males than females when measuring STEM dispositions, looking at changes during programs is one way to determine how programs may impact females as well as males. This finding is consistent with prior research that girls have lower interest in mathematics (United States Department of Education 2006) and that girls are more interested in careers where they can make a difference in the world helping others (Ceci et al. 2009).

Cumulative findings indicate that future studies should focus on pre-post surveys measuring changes due to interventional programs aimed at making STEM curriculum and STEM activities more in line with how we believe students prefer to learn—in hands-on, active learning environments in which the students are engaged in projects that have relevance to the real world.

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**Ethical standard** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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