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Narrowing the Gender Gap: Enduring Changes in Middle School Students' Attitude Toward Math, Science and Technology

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Abstract

Middle School students from rural school districts participated in a summer STEM program with academic year follow-up requirements. Both males and females showed increased interest and confidence regarding math science, technology, and problem-solving. Furthermore, these gains continued beyond the immediate impact of summer program participation and were intact nine months later. However, perhaps the most interesting results from this study are the effects that the program had on closing the gap between males and females on several of these important indicators.

As the economic base in the U.S. continues to evolve, an increasing number of jobs require skills in science, technology, engineering, and mathematics (STEM). Alas, the United States is experiencing educational deficiencies in these vital STEM fields (e.g., Terry & Hammonds, 2007). Children throughout our educational system are low performing in these areas as compared to many other countries. Adult U.S. citizens show little interest in studying and/or pursuing degrees in these areas as well. As a result, the National Science Foundation has called for new efforts in teaching diverse students of all ages about the significance of STEM fields and assisting them to see the benefits of careers in these disciplines (see NSF, 2006).

The problem starts early. Haladyna and Thomas (1979) showed students' attitudes toward school in general, as well as toward key academic domains such as mathematics and science, decrease as children get older. Many classic studies (e.g., Epstein & McPartland, 1976; Harter, 1981; Marsh, 1989) have found that motivation, self-concept of ability, and positive attitudes toward school decrease markedly during grades six and seven, or following the transition into middle school (Berndt & Hawkins, 1988). Specifically, early adolescence often seems to mark the beginning of a downward spiral in school-related behaviors and motivation, even leading to academic failure and dropping-out of school for many students (Eccles, Wigfield, Midgley, Reuman, Mac Iver, & Feldlaufer, 1993).

Some researchers have sought a link between the transition from elementary to middle school to explain these motivational declines (e.g., Blyth, Simmons & Carlton-Ford, 1983; Eccles, et al., 1989; Simmons & Blyth, 1987). Many believe it is an age-related phenomenon associated with pubertal changes and cognitive maturation. For example, Eccles et al. noted students' self-esteem is lowest in the fall of the seventh-grade year. Related, they found student enjoyment of math was similar during the fall and spring of sixth-grade, but declined across the transition into seventh.

Additionally, research also suggests that there can be a mismatch between characteristics of the classroom environment in traditional middle school grades and early adolescents' developmental level (Eccles, et al., 1993). They found that often, middle school math teachers control their students more and provide less self-efficacious decision-making opportunities as compared to sixth-grade elementary school teachers. As such, students' devaluing of mathematics could be related to differences in perceived teacher support. That is, they found that when students felt they were receiving a high level of support their value of math did not change, but when students felt they were not receiving a high level of support their value of math steadily declined across the two years of the study.

These problems generally seem worse for girls than for boys. During elementary school girls perform as well as (or better than) boys on most aspects of math and science, but Orenstein (1994) notes that girls are not as likely to retain any early affection for math and science. For example, Sanders & Nelson (2004) reported no gender difference in math at the age of 9, minimal difference at the age of 13, but a large difference by the age of 17. It has been noted by many researchers that as girls progress through middle school both their confidence and achievement in math and science falls at an alarming rate (see AAUW, 1995).

This drop in confidence seemingly occurs before the decline in achievement, and likely contributes to it. As girls lose confidence they begin to fall behind in math and science, taking fewer advanced math and science classes than boys do as they progress through high school (Sanders & Nelson, 2004). The U. S. Department of Commerce, Economics and Statistics Administration (2011) indicates that while women represent half of the American workforce, they are greatly underrepresented in STEM careers, holding less that 25% of STEM jobs. Additionally, the wage gap between males and females is much smaller in STEM related careers, with women earning 33% more than those in non-STEM careers. This disparity represents an underutilized resource for not only the economy, but for women.

Having a competent workforce in the STEM fields is crucial to the United States' growth and development according to the U.S. Department of Commerce, Economics and Statistics Administration (2011). Numerous studies have reported on STEM-type projects designed to generate interest and change student's attitudes about these fields, but few have examined the persistence of these attitudes beyond the immediate post-treatment period (for examples, see Jeffers, Safferman, & Safferman, 2004, who reviewed over 50 programs).

Stake and colleagues (e.g., Stake and Stanton, 2005; Stake and Mares, 2001) indicate that numerous programs, including summer camps held on university campuses, have had a positive impact on student attitudes toward science and mathematics (as well as academic achievement). Others, such as Matson, DeLoach, & Pauly (2004) indicate that even short interventions such as a "Robot Roadshow" can produce immediate benefits for students. Recent findings on this point include Nadelson and Callahan (2011), who examined two different programs for middle to early high school students and found a significant change in attitudes and perceptions about engineering. Similarly, Elam, Donham, & Solomon (2012) reviewed a two week program and also found an increase in attitudes toward engineering. While this program included academic year follow-up activities, key measures were only completed after the summer portion.

This paper examines the *enduring* attitudes and perceptions of middle school students towards STEM and college based on a post-treatment measure completed nine months after a summer program.

Project Description

The M^2T^2 (Maximizing Motivation, Targeting Technology) project was funded by the Innovative Technology Experiences for Students and Teachers (ITEST) program at the National Science Foundation. M^2T^2 targeted middle school students in rural schools who met the selection criteria of being low SES and having a non-college graduating parent or parents. Students were encouraged to apply by teachers in collaborating schools. Unlike many projects of this type, high academic ability was not a pre-requisite for attendance and the focus was on selecting those students who "needed a spark" to reach their ability and see beyond their familial circumstances. The goals of the project included generating positive attitudes toward STEM fields, increasing awareness and interest in STEM careers, influencing students to seek college attendance, and having them consider a STEM major.

Each of the partner school districts identified 2 or 3 middle school math, science, or technology teachers who would participate in the project along with the students and assist in student recruitment and selection. The selected students and their parents met with project staff to go over highlights of the project, secure required permissions, and conduct the baseline assessments.

M^2T^2 consisted of a two-week, non-residential summer program held at a Texas university and then academic year meetings facilitated by the participating teachers at their schools. The summer portion introduced the students (and school teachers) to various science concepts using two primary venues: computer game programming and a robotics project. These two areas were selected for their immediacy in showing how STEM related to the child's own world (e.g., computer games, robotic toys). Perhaps importantly, during the camp participating teachers were primarily in the same "student" role as the children from their districts. During the camp, the teachers served as facilitators between students and project staff, but they also participated in the same activities as the students. Getting to know students that would be or had been in their classes in an out of school setting allowed for an heightened learning environment during the school year. Furthermore, the program benefited the teachers who attended the camp by providing them with programming experience as well as activities they could use in their own classrooms to demonstrate scientific and mathematical principles.

Instruction was purposefully conducted by university undergraduate students with oversight by project staff (faculty) members. Undergraduates were selected for the camp based not just on academic competency, but also based upon their own backgrounds. That is, where possible, students from modest and rural backgrounds were utilized, and women were especially valued for their potential as role-models. Information on STEM careers, how to fund higher education, and similar topics were also incorporated into the camp.

Hands on lessons related to mathematics and science topics were integrated as needed to aid in understanding of programming related concepts. For example, the designing and programming of a computer game or robotic movements represented increased knowledge in several areas that were significant to the M^2T^2 program. Each game required some understanding of the Cartesian coordinate system as they employed an X and Y axis. Because the games involved movement along both axes, students were required to understand the difference between representation of coordinates on the computer screen and those same coordinates in mathematical terms. The students were also exposed to ideas such as the Pythagorean Theorem and its relationship to determining distance between points. They then applied this knowledge within the game design. By programming a chase between the games' heroes and villans, students were able to witness the theorem in action.

In addition, the internationally acclaimed aviatrix Jeana Yeager, who co-piloted the first nonstop, non-refueled flight around the world, told her story and interacted closely with the students for several days of the camp. Lessons related to aeronautics and the science of flight were incorporated to take advantage of the availability of the aviation pioneer. Students also gained an understanding of speed, acceleration, and velocity. For example, students learned that to make an object move, they had to select both a direction and a desired speed. Concepts such as mass and gravitational acceleration were also addressed as part of the game design and robotics project. While attitude and motivation rather than content knowledge were the major focus, students gained significant knowledge regarding applications of math and science as well as using those concepts within a technological framework.

The students and teachers continued to work on designing and programming a computer game as an ongoing academic year project to help maintain students' interest and involvement in STEM subjects. The majority of students were novices in computer programming; therefore, the ability to design and program their own game or robot represented a tremendous increase in knowledge and skills. Academic year meetings held approximately twice a month allowed the students to continue working on ideas from the summer with the goal of presenting their own computer game and completing a robotics project at a culminating event held at the university in the spring. Project staff visited some of these academic year meetings and provided ongoing guidance as necessary through email or phone.

Method

This paper presents results from two different project years, and each year included different collaborating school districts, different staff, and different students. The M^2T^2 Questionnaire was designed to measure participants' interest in, aptitude for, and enjoyment of science, mathematics, technology, and other academic areas such as English and social studies. Additionally, the questionnaire assessed participants study habits and related behaviors. For example, participants were given statements such as "Outside of school, I enjoy doing things related to science." The questionnaire focused on general science and mathematics related items rather than technology focused items due to middle school students' probable confusion of technology terminology. Our experience with rural middle school students indicated their concept of technology is using computers for word processing, internet research, or drill-based games. In general, the M^2T^2 Questionnaire was similar to other science attitude survey instruments such as the Test of Science Related Attitudes (Fraser, 1978) however, staff felt that none of the available instruments entirely meet project needs. Given that the items developed were fact-based behaviors and not summed to form hypothetical constructs, no assessment of internal validity was warranted.

The questionnaire was a 5-point Likert-type measure with scaled responses ranging from "a lot like me," to "not like me at all." Participants completed the questionnaire before beginning the summer program, then at the beginning of the fall semester after the summer program, and finally during the following spring.

Initial Year Participants

Data from 32 students were available for analysis. These participants were predominantly sixth graders (21) with some fifth (1), seventh (9) and eighth graders (1) included. The group consisted of 17 females and 15 males with ethnicity at least representative and usually over-representative in terms of minorities as compared to their rural school population. Parental education was self-reported as follows, with some participants not responding: for fathers 6 did not complete high school; 8 had graduated from high school; 14 had some college, and 2 held a bachelor's degree. Regarding the mothers, 8 never completed high school; 3 completed high school, 17 had some college, and 1 held a bachelor's degree.

Subsequent Year Participants

Data for 34 students were available for analysis. The participants were predominantly sixth graders (21) with some seventh (12) and eighth graders (1) included. The group consisted of 18 females and 16 males with ethnicity at least representative and usually over-representative in terms of minorities as compared to their rural school population. Information regarding parental education was: for fathers 13 reported not completing high school; 14 had graduated from high school; 1 had some college, and 1 held a bachelor's degree. Regarding the mothers, 17 never completed high school; 7 completed high school, 8 had some college education, and 1 held a bachelor's degree.

Gender-Based Results and Discussion

Given the sample size was small, a Mann-Whitney U test was conducted to determine if there were any differences (at $p < .05$) between males and females on responses to the questionnaire. Students in the two years revealed different response patterns and as such are shown separately.

Initial Year Participants

Pre-test results indicated that males endorsed higher ranks than females on 16 items relating to science, mathematics, technology and problem solving (see Table 1). However, post-test results revealed that the program had a considerable impact on females' ideas about their abilities in these areas. At the post-test, males maintained higher rankings on only 3 of these items. Of particular interest is the finding that even these remaining differences in attitude about science had disappeared by the spring follow-up. This indicates that the program not only had immediate effects, but these effects carried over into the students' regular educational experiences with the results that females continued to make relative gains in their interest in science and STEM related abilities.

The differences that did emerge in the spring follow-up had to do with development of personal work styles and practices. (see Table 2).

In summary, while there are potential intervening variables it appears the initial M^2T^2 program was successful in helping female students make gains regarding their interest in matters related to STEM areas. Furthermore, these benefits extended beyond the end of the summer program. By the spring follow-up survey, the remaining differences between genders focused on work styles and preferences (e.g., seeking help when needed). Overall, the program contributed to helping close the gender gap regarding science, math, and technology. Most importantly, the benefits continued beyond the end of the program and had a positive impact after the participants returned to school.

Item	Z score	Significance
Being good at science	-2.49	.013
Enjoying doing things with science	-2.09	.036
Enjoying learning about math	-2.46	.014
Enjoying doing things with math	-1.97	.049
Concentrating on a computer while using one	-2.25	.024
Sometimes changing their way of studying	-2.34	.019
Enjoying working on a difficult problem	-2.60	.009
Being good at using technology	-2.63	.008
Seeing how new things connect to things they already know	-2.34	.019
Considering different ways of solving problems	-1.99	.046
Finding different kinds of materials to work with	-2.09	.036
Examining unknown issues to try to understand them	-2.85	.004
Inventing new methods when one way does not work	-3.27	.001
Liking learning about atoms and molecules	-2.37	.018
Liking inventing things	-2.54	.011
Figuring out answers when there isn't much information	-2.09	.036
Post-test items with significant differences in endorsements by gender		
Enjoying doing things with science	-2.14	.003
Enjoying learning about science	-3.05	.002
Liking learning about atoms and molecules	-2.28	.022

Table 1. Pre-test items with significant differences in endorsements by gender

Item	Z score	Significance
Will continue working on a problem	-2.26	.024
Enjoy working at a difficult problem	-2.08	.037
If I don't do well, I try to find out why	-2.26	.024
Liking learning about atoms and molecules	-2.53	.011

Table 2. Follow-up items with significant differences in endorsements by gender

Subsequent Year Participants

Pre-program results unexpectedly showed minimal gender-differences at baseline: Males gave more positive endorsements than females on only four survey statements (see Table 3).

Item	Z score	Significance
My favorite subject is science	-2.11	.03
Study harder than my friends	-2.91	.004
Like learning about plants	-2.11	.03
Like imagining/inventing new things	-2.11	.03

Table 3. Pre-test items with significant differences in endorsements by gender

Item	Z score	Significance
Subject I do best in is science	-2.11	.036
Enjoy working on difficult problems	-2.05	.041
Prefer to work in groups	-2.12	.034
Like learning about animals	-2.10	.035
Like learning about the environment	-2.22	.027
Get frustrated when don't have enough information	-2.22	.027

Table 4. Follow up-test items with significant differences in endorsements by gender

However, post-test results still revealed that the M^2T^2 program had a considerable impact on females' ideas about their abilities in STEM areas. Results of the post-test survey demonstrated that females no longer indicated a lower preference for science than did males. Other changes in endorsements reflected new preferences for study topics and styles.

Trends in the spring follow-up analysis indicated that students were continuing to develop particular study and work preferences as well as continuing to define areas of study that were of particular interest (see Table 4). Indeed, positive changes in attitude persisted even though females did not consider science their best subject. Because one aim of the program was helping students explore future academic and career options, this positive change was in keeping with the goals of the program.

In summary, the results from both years suggest that the program contributed to reducing the gender gap regarding interest in math, science and technology. In addition, these effects extended beyond the end of the program and continued to influence students as they resumed their regular studies in the fall.

External evaluation

Further data regarding the M^2T^2 program was collected each year by the project external evaluator. Following completion of the summer program, students were asked to provide retrospective data regarding changes in attitude that occurred over the course of the camp. Students used a 6-point Likert scale (1- strongly disagree through 6- strongly agree) to record their level of agreement with each statement. Students rated both how they would answer at the time of the survey and how they believed they would have answered at the beginning of the camp.

A Mann-Whitney U test was conducted to determine if there were any differences (at $p < .05$) between how students believed they would have responded at the beginning of the camp and how they felt at the end of the camp. Significant differences are reported in the table below. The results indicate that students had come to value STEM related careers and activities. They also indicated that they were more comfortable working with technology and had come to recognize the usefulness of science, math, and technology in everyday situations. Finally, students indicated that they were more likely to go to college after having attended the camp because they had a better understanding of the importance of a college degree.

Question	z-score	p-value
How interested are you in gaming programming?	-4.23	<.001
How interested are you in robotics?	-3.29	.001
How likely do you think it is that you will go to college?	-1.94	.05
How important do you think it is to go to college?	-4.29	< .001
How comfortable are you working with technology?	-4.31	< .001
How useful do you think math is in solving everyday problems?	-4.18	< .001
How useful do you think science is in solving everyday problems?	-4.27	<.001
How useful do you think technology is in solving everyday problems?	-4.23	<.001
How important do you think it is for you to understand science?	-3.99	<.001
How important do you think it is for you to understand technology?	-3.78	<.001

Table 5. Retrospective data: Initial year

General Discussion

This program attempted to provide experiences that would enhance any students' interests in math science, technology, and problem-solving, but was especially designed for groups that are perhaps unlikely to explore these fields. Participating males and females increased the levels of endorsement for, and confidence in, math, science, technology, and problem-solving. A diminution in gender differences continued beyond the immediate impact of program participation and was intact months later.

Indeed, perhaps the most interesting results from this study were the role the program had on closing the gap between males and females on several of the questions. The number of items with significant differences between males and females decreased and on many items where there were significant differences, the gap was closed substantially. Additionally, on the follow-up questionnaire, observed gender differences shifted to items regarding persistence and problem-solving. Although we are generally speaking of gains, and not a "regression to the mean," in either case such findings indicate that the effects of the program not only lasted but grew stronger over time. Presumptively this owed to following up on camp exercises as students gained experience in their own classroom.

Several features of the program design can be consid-

Question	z-score	p-value
How interested are you in gaming programming?	-4.52	<.001
How interested are you in robotics?	-3.67	<.001
How likely do you think it is that you will go to college?	-3.02	.003
How important do you think it is to go to college?	-4.35	<.001
How comfortable are you working with technology?	-3.90	<.001
How useful do you think math is in solving everyday problems?	-4.45	<.001
How useful do you think science is in solving everyday problems?	-4.25	<.001
How useful do you think technology is in solving everyday problems?	-4.25	<.001
How important do you think it is for you to understand science?	-4.57	<.001
How important do you think it is for you to understand technology?	-4.47	<.001

Table 6. Retrospective data: Subsequent year

ered when explaining this success. While many camps and programs are for academically high-achieving students (perhaps reinforcing the stereotype of science and math as "elitist" careers; see Jacobs, 1998), the target population for this project was average or underperforming students. In addition, featuring role models who came from similar circumstances as the participants provided the belief in these children that "anything is possible." Jeana Yeager, who accomplished a great first in aviation interacted with participants on a personal level, talking about her rural upbringing and the importance of persistence in meeting goals. Likewise, several of the undergraduate student instructors were purposefully selected because they were able to share information about their rural upbringing, struggles in school, difficulty with funding their education, and how determination was the key to success.

The inclusion of teams of students from small rural districts who were accompanied by teachers from their campuses was essential to success. This allowed for developing a critical mass of students in one school interested in STEM that would have the support of one another in succeeding in these subjects. Additionally, having teachers learning alongside the students created a spirit of enduring collaboration. In these small districts there is often only one math and science teacher per grade level, and the students were almost certain to be in class with teachers with whom they had established a prior working relationship.

The external evaluation also included post summer focus group interviews and spring follow up phone interviews with the participating teachers. While a detailed examination of the interviews is beyond the scope of this article, several findings are worth mention that provide corroboration of the student gains. Teachers indicated the students: had an increased interest in math, science, and technology, were more attentive to completing class assignments, are thinking at a higher level, and are now interested in math, science, and engineering as careers. Additionally, some teachers pointed to how the project influenced non-camp participating students interest in math and science, and benefited "kids who were not the stars in their districts." One teacher shared that he/she believed that participation in this project will actually help to "keep some of the students in school."

In summary, both the survey results and retrospective responses indicate that the M^2T^2 program was successful in increasing students' knowledge of and interest in academic and career opportunities related to math, science, and technology. Furthermore, these attitude changes remained intact beyond the conclusion of the program. Given the relatively low number of students who enter these disciplines and the disparity between the number of males and females, programs such as M2T2 can provide a valuable resource in encouraging greater involvement in these areas. One teacher summed up the feelings of all the teachers about the experience with the following comment: "This is definitely making a difference in the lives of the kids. It is opening doors to kids who have never been on a college campus."

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