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Contrasting Perceptions of STEM Content and Careers

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Abstract

Analysis of baseline attitudinal data gathered from a National Science Foundation Innovative Technology Experiences for Students and Teachers project uncovered large contrasts between the perceptions of practicing professionals and students toward science, technology, engineering, and mathematics (STEM) disciplines and careers (Tyler-Wood, Knezek, & Christensen, 2010). These findings have been reconfirmed in a second year analysis based on new data and are reported in this paper. The pattern of findings suggests that university teacher preparation candidates hold attitudes similar to middle school students, while the faculty (the educators of teacher preparation candidates) have attitudes similar to STEM education professionals. Additional findings based on disaggregated data are reported. For example, middle school students appear to have more positive perceptions of science, mathematics, and engineering than do the university preservice teachers surveyed, who are destined to be middle school teachers.

Conceptual Foundations: The Case for a Focus on STEM

A continued concern for society in general and particularly educational institutions is meeting the demand for highly skilled workers in science, technology, engineering, and mathematics (STEM) disciplines. Decades of inadequate preparation in mathematics and science have resulted in a deficit of qualified workers that will continue to generate a widening disparity for the United States in the global industrial workplace (Cooney & Bottoms, 2003).

The United States is increasingly reliant on the STEM workforce to maintain leadership in the world economy (National Science Board, 2003). Employment projections have estimated that careers involving computers, mathematics, engineering, and life and physical sciences will experience a combined 90.8% growth between 2002 and 2012. Computer and mathematical occupations are projected to add 1.1 million jobs to the labor market during this same time period (Hecker, 2004), while 1.2 million additional professional, scienti?c, and technical jobs are projected to be added between 2008 and 2018 (Lacey & Wright, 2009). The state of California alone is projected to have at least one million fewer college graduates than it needs in 2025 (Offenstein & Shulock, 2009).

This workforce shortage is particularly evident in STEM occupations for California and across the U.S. Of 123 STEM occupations requiring postsecondary education, nearly half are likely to have severe shortages (Offenstein & Shulock, 2009). Clearly, it is critical to increase the number of qualified students in STEM who successfully progress through challenging STEM curriculum in our school districts and institutions of higher education.

Meanwhile, many U.S. citizens are underprepared to use STEM applications in their workplace. Hurley and Thorp (2002) reported that a sizeable proportion of high school seniors indicated the avoidance of mathematics and science courses as an important factor in career decision-making, with girls more likely than boys to indicate STEM avoi dance as a factor influencing career choice. Limited completion of critical STEM coursework can restrict the range of future career opportunities available to an individual (Betz, 1992). Hamilton (2001) indicated that often workers who avoided STEM courses earlier in their education have difficulty succeeding in an increasingly STEM-oriented workplace.

Lack of STEM preparation may explain some of the unemployment issues that U.S. workers are facing as more and more STEM-related jobs are exported to other countries. As early as 1998, Tapia argued that one factor fueling the growing underclass in the U.S. was the limited job options available to those lacking mathematical, computing, and scientific skills (Tapia, 1998).

Paulson (2009) has researched the relationship between STEM achievement and teachers' attitudes toward science. Paulson indicated that part of the problem with increasing STEM achievement lies with the attitudes of both students and teachers. Science is viewed as a challenging, difficult subject, mastered by only a select few (Crovrther & Bonnstetter, 1997). This attitude appears prevalent and seems to permeate science achievement for all students in U.S. schools.

The U.S. elementary teaching force continues to lack knowledge and confidence in science concepts (Fulp, 2002). Paulson (2009) said that the quantity and quality of elementary science teaching is inversely related to increased accountability for skills such as reading under national and state legislation. As the emphasis on reading increases, teachers are held less accountable for science content, an area toward which teachers may already feel intimidated.

The relationship of teacher attitudes to those of their students has been established with respect to the "T" in STEM, and there is empirical evidence for transference in other STEM disciplines as well. For example, Christensen (1997, 2002) demonstrated that conducting needs-based technology integration training for elementary school teachers resulted in not only more positive attitudes and skills in the teachers, but also resulted in more positive attitudes toward technology in their students.

Tyler-Wood, Knezek, and Christensen (2010) used student scales common to the Christensen (1997) study to show that some of the Computer Attitude Questionnaire (CAQ; Knezek, Christensen, Miyashita, & Ropp, 2000) learner disposition measures were related ($p < .05$) to STEM career interests. CAQ learner disposition measures utilized in the 2010 study included Computer Enjoyment, Computer Importance, Motivation, Study Habits, Empathy, Creative Tendencies, and Attitudes Toward School.

STEM Career Interest, when viewed as a total scale score, was found to be positively correlated with Creative Tendencies ($r = .53$, $p < .0005$), Computer Importance (for schooling and career) ($r = .54$, $p < .0005$), Motivation ($r = .42$, $p < .001$) and Attitudes Toward School ($r = .42$, $p < .001$) (Tyler-Woodet al., 2010). The implication of the latter findings is that teacher attitudes can impact STEM career interests as well as many other dispositions in students.

Other researchers have established a critical need for instrumentation designed to measure teachers' as well as students' attitudes toward STEM. Watters, Ginns, Enochs, and Asoko (1995) stressed that despite adequate background content knowledge a teacher's attitude toward science can impact teaching methodologies and, subsequently, the amount of time spent in teaching science content. To ensure both the quantity and quality of science instruction, instrumentation must be developed that allows researchers to measure teachers' attitudes toward STEM subjects (Koballa & Crawley, 1985). Also important is identifying instrumentation with the ability to predict successful student entrance into a STEM career.

Gender differences in STEM interest and achievement have been the subject of previous discussions in the scholarly literature. Educators generally accept that boys have higher academic achievement in STEM than girls. However, some literature suggests that the gender gap is less of an ability gap than a gap in perceptions of science careers. Indeed, girls achieve as well as or even better than boys on many indicators of educational achievement in elementary, secondary school, and college (Freeman, 2004).

Although some gender differences still exist in science and mathematics, many gender gaps appear to be closing (Freeman, 2004). Freeman found that scores fluctuated year by year, but the average scores of boys in calculus, computer science, and science on Advanced Placement examinations were higher than those of girls. However, there was little difference between boys' and girls' scores on the mathematics National Assessment of Educational Progress (Freeman, 2004).

While the existence of a gender gap and the actual size of the gender gap in STEM academic achievement are questionable when various datasets and test scores are compared, the fact that women are underrepresented in STEM careers is considered indisputable (Blickenstaff, 2005). Van Langen, Bosker, and Dekkers (2006) studied the influence of the gender achievement gaps worldwide in secondary education on the STEM participation of women. Even though considerable differences exist among countries, the results indicated that the smaller the gender achievement gap for mathematics and science literacy between males and females in secondary education, the greater the STEM participation of females in higher education.

Weinburgh (1995) conducted a meta-analysis of the literature on gender differences in students' attitudes toward science. He explored the correlation between students' attitudes toward science and student achievement, concluding that boys displayed more positive attitudes toward science than did girls and that attitude toward science was highly correlated to science achievement.

Baram-Tsabari, Sethi, Bry, and Yarden (2006) noted that the attitude of girls toward science became increasingly negative with age. To increase the number of females in STEM careers, instrumentation that can measure perceptions of STEM subjects would seem critical. Instrumentation is needed to determine which programs are successful at increasing female students' perception of STEM subject.

Issues with inadequate STEM preparation in the early grades ultimately play a role in decreased social mobility and increased levels of economic disparity for minority and underrepresented subgroups (Brown & Campbell, 2009). Even an attitude that is passed on to the students from a teacher regarding mathematics and science can be influential in motivating a given student to be interested in learning more. Clearly, determining factors that lead to better STEM preparation in the early grades is important.

Instrumentation is needed to measure factors such as attitudes that have been shown to predict success in STEM coursework and future choice of a STEM career. Interventions based on accurate diagnosis and prescription would then have a logical basis for beginning STEM initiatives and making appropriate adjustments in STEM training programs for both teachers and students.

Research Questions for the Study

The research questions addressed by the current study include the following:

- Based on the STEM Semantics Survey (described later), what are the similarities and differences among the STEM-related dispositions of selected STEM education professionals, elementary/middle school preservice educators, and middle school (grade 6-8) students?
- Based on STEM Semantics Survey and Computer Attitude Questionnaire (described later) scales, what are the primary distinctions in STEM-related dispositions between selected preservice educators and middle school (grade 6-8) students?
- Based on STEM Semantics Survey and Computer Attitude Questionnaire scales, what are the primary distinctions in the area of STEM-related dispositions between male and female middle school (grade 6-8) students?

Methodology

About the ITEST Project

Middle Schoolers Out to Save the World (MSOSW) is a National Science Foundation (NSF) Innovative Technology Experiences for Students and Teachers (ITEST) Project funded to span 2008-2011. The MSOSW project personnel train middle school teachers (grades 6-8) to work with their students to measure standby power usage or "vampire power." Standby power consumption is an issue in all U.S. homes. Electronics and appliances that remain plugged in or in standby mode typically consume between 5% percent and 26% of the amount of power appliances require when in full use (Ross & Meier, 2000) and may consume up to 40% of the total energy used by electronics in a typical U.S. home (U.S. Department of Energy, as cited by Magid, 2007). One goal of the MSOSW project is to encourage future scientists to pursue further study in the area. A broader goal is to promote interest among young students in future STEM careers.

Participants and Activities

In the MSOSW project, approximately 600 sixth, seventh, and eighth graders from middle schools in Louisiana, Hawaii, Maine, Texas, and Vermont are participating to provide home energy use data under supervision of their teachers. For this project, entire classrooms of students were selected based on (a) voluntary participation of teachers whose schools matched specific urban, suburban, or rural characteristics and were located in one of two major climate zones in the US, and (b) consent forms signed by the students' parents.

Once the data are retrieved from the participating classrooms, project personnel assist students and teachers with developing optimum scenarios for conserving energy and reducing production of greenhouse gases in local communities. Participating teachers are receiving ongoing professional development to carry out the project. Students and teachers are using online software tools to record and analyze their data and create projections of future energy use based on assumptions of modifications in energy use. Students and teachers are communicating their results within the project via information communication technology.

Research Agenda

Project staff first analyzed the baseline status of the major project constituencies—grade 6-8 students involved in the project, a sample of preservice teacher educators at the researchers' university, and a sample of STEM education professionals—and then examined effects of the project on students' and teachers' changes in attitude and interest in science, technology, engineering and mathematics. Students' gains in content knowledge were examined as well. Content knowledge gains due to project activities have been verified and reported in external evaluation and annual reports (Knezek, Christensen, & Tyler-Wood, 2009, 2010; Nolte & Harris, 2010). This paper focuses on the attitudinal discrepancies found among major project constituencies. It also addresses differential males versus female changes in attitudes and interests related to project participation.

Research Instruments

The STEM Semantics Survey (see Appendix A, pdf download) is a new instrument created to assess general perceptions of STEM disciplines and careers using Semantic Differential adjective pairs from Osgood's (1962; Osgood, Tannenbaum, & Suci, 1957) evaluation dimension. This survey was created by adapting Knezek and Christensen's (1998) Teacher's Attitudes Toward Information Technology Questionnaire (TAT), which was itself 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 STEM subjects. A fifth scale representing interest in a career in STEM was also created. Each of five scales consisted of a target statement such as "To me, science is:" followed by five polar adjective pairs spanning by a range of seven choices. For example, "To me, science is: exciting _ _ _ _ _ _ _ unexciting." Internal consistency reliabilities for middle school student perceptions of science, math, engineering, technology, and STEM as a career have typically ranged from alpha = .84 to alpha = .93 (Tyler-Wood, Knezek, & Christensen, 2010). These numbers are in the range of "very good" to "excellent" according to guidelines provided by DeVellis (1991).

The 2009-2010 MSOSW middle school students also completed pretest and posttest items spanning the following nine scales on the Computer Attitude Questionnaire (CAQ):

- Computer Enjoyment – amount of pleasure derived from using computers
- Computer Importance – perceived value or significance of knowing how to use computers; relevance to school work
- Computer Anxiety – discomfort with thought of using computers; usually coded as Computer Comfort
- Motivation – unceasing effort; perseverance; never giving up
- Study Habits – mode of pursuing academic exercises within and outside class
- Empathy – a caring identification with the thoughts or feelings of others
- Creative Tendencies – inclinations toward exploring the unknown, taking individual initiative, finding unique solutions
- Attitudes Toward School – perceived value or significance of school
- Self Concept – perception of self; self-esteem. (Knezek et al., 2000)

The core of the CAQ is 80 Likert-style items with five multiple-choice responses ranging from 1 = *strongly disagree* to 5 = *strongly agree* (Knezek & Christensen, 1995). Reliabilities for the computer attitude and learning disposition scales of the CAQ have been consistent for middle and secondary schools students for several years. For example, for 2006 data gathered from 5,045 grade 6-12 students attending one of the Texas school districts in the current MSOSW project, internal consistency reliability indices (Cronbach's alpha) ranged from r =.71 to r =.91 for the previously listed scales (Knezek & Christensen, 2008).

Results

Year 1 Findings from Baseline Data

During the spring and summer of 2009, baseline data were gathered from students, K-12 teachers, and two groups of university-level professionals in order to judge the consistency (reliability) of the measures as well as their appropriateness and relevance (validity) for evaluating ITEST projects. Specifically, data were gathered from a purposely broad range of relevant convenience samples, including two classes of middle school students (n = 60) spanning grades 6, 7, and 8; from their project teachers (n = 11); from two university classes of preservice educators (n = 58)**;** and from two groups of professional practitioners made up of university professors attending the Society for Information Technology and Teacher Education (SITE) annual conference (n = 14), and principal investigators and project evaluators (n = 29) attending an annual meeting about NSF projects. Descriptive statistics for these baseline data are shown in Table 1.

Reliability Analysis for Baseline Data

One purpose for gathering baseline data was to assess the measurement consistency of the instruments selected for the MSOSW project. The STEM Semantics Survey was analyzed and found to have respectable to excellent internal consistency reliability (as defined by DeVellis, 1991), as well as good content, construct, and criterion-related validity for the areas assessed (Tyler-Wood et al., 2010). Cronbach's alpha for the individual scales on the STEM Semantics Survey (see Appendix A, pdf) ranged from .78 to .94 across the five constructs represented. These results were judged to be acceptable to assess anticipated changes resulting from MSOSW ITEST project activities (Tyler-Wood et al., 2010).

Table 1
Descriptive Statistics for Five Groups Completing STEM Semantics Survey

Scale	Group	*N*	Mean	*SD*
Science	Preservice teachers	58	5.04	1.42
	ITEST summit participants	29	6.50	0.71
	SITE conference attendees		6.27	0.96
	MSOSW teachers	11	6.62	0.54
	MSOSW students	60	5.48	1.17
Math	Preservice teachers	58	3.73	1.53
	ITEST summit participants	30	5.24	1.53
	SITE conference attendees	14	5.44	1.57
	MSOSW teachers	11	5.65	0.99
	MSOSW students	60	4.49	1.67
Engineering	Preservice teachers	58	3.49	1.37
	ITEST summit participants	31	5.87	1.20
	SITE conference attendees	13	5.31	1.35
	MSOSW teachers	11	5.62	1.12
	MSOSW students	60	4.94	1.68
Technology	Preservice teachers	58	5.56	1.02
	ITEST summit participants	30	6.31	0.90
	SITE conference attendees	14	6.87	0.27
	MSOSW teachers	11	6.30	0.91
	MSOSW students	60	5.69	1.33
Career	Preservice teachers	58	4.62	1.56
	ITEST summit participants	31	6.28	1.04
	SITE conference attendees	14	6.40	0.64
	MSOSW teachers	11	6.20	1.21
	MSOSW students	60	4.91	1.58

Note: Scale scores based on incomplete ratings were not included in descriptive statistics; that is, if a respondent failed to indicate a preference for one or more of the adjective pairs, then the entire scale of incomplete data for that individual was not used in the computations.

Comparisons Among Baseline Data Groups

Sufficient sample sizes were gathered to analyze differences in the group mean (average) scores for the five groups who had taken the STEM Semantics Survey in 2009. A more complete description of these groups follows:

1. Fifty-eight elementary/middle school teacher preparation candidates at a large Midwestern U.S. university who were enrolled in a technology integration course during spring 2009. These students were a convenience sample consisting of two of nine sections of this course typically offered each semester. Typically, second-year (sophomore) or third-year (junior) teacher preparation candidates are enrolled in this required course offered at the beginning of the methods

sequence. Teacher candidates typically have completed either one science, math, or technology-specific methods course or none prior to enrolling in this class.
2. Thirty-one NSF ITEST Project principal investigators and evaluators attending the 2009 ITEST Summit annual meeting in Washington, DC, during February 2009. We envisioned that ITEST project director and evaluator scores would be among the highest (most positive) of any we gathered. These would form a standard toward which we would have our students aspire.
3. Fourteen teacher educators (faculty) attending the Society for Information Technology and Teacher Education (SITE) Conference in March 2009**.** These participants were generally university faculty who were the "teachers of teachers" for educators planning to use technology in the K-12 schools.
4. Eleven teacher/liaison participants in the summer 2009 training sessions for MSOSW teachers and project personnel in Vermont**.** These respondents represented all but one of the classroom teachers participating in project at the time data were gathered.
5. A combined sixth- through eighth-grade sample from a Hawaii summer STEM enrichment class and a Vermont middle school classroom during May-June 2009. Surveys were completed by all students enrolled and in attendance for each class.

Tabular results for one-way analysis of variance procedures completed on these data are detailed in a previous publication by the authors (Tyler-Wood et al., 2010). As is graphically displayed in Figure 1, the perceptions of 2009 ITEST Summit participants (ITEST project principal investigators and evaluators), 2009 technology faculty (SITE conference attendees), and MSOSW teachers providing data in the summer of 2009 were generally higher than those of spring 2009 university preservice teacher candidates or MSOSW middle school students who provided data in the spring of 2009.

Perhaps predictably, the ITEST summit participants had the highest perceptions of engineering, the selected technology educators (SITE conference attendees) had the highest perceptions of technology, and the mathematics and science middle school teachers (MSOSW teachers) had the most positive perceptions of science and mathematics. When all adult scores were combined, this composite group was significantly higher than the undergraduate preservice candidates in all categories ($p < .003$).

Furthermore, teacher preparation candidates were lower ($p < .05$) than all groups who were holding positions in professional education careers (technology educators attending the SITE conference and ITEST summit participants), and the middle school students were lower than all groups holding professional educator positions in all measures except in mathematics and engineering. With regard to perceptions of mathematics and engineering, MSOSW middle school students were not significantly different ($p < .05$) from the technology educators. The preservice teachers were generally not significantly different ($p < .05$) from the middle school students in their perceptions of STEM disciplines and careers. Exceptions were found in perceptions of mathematics and engineering, where the middle school students had more positive perceptions ($p < .05$) when compared to preservice teachers.

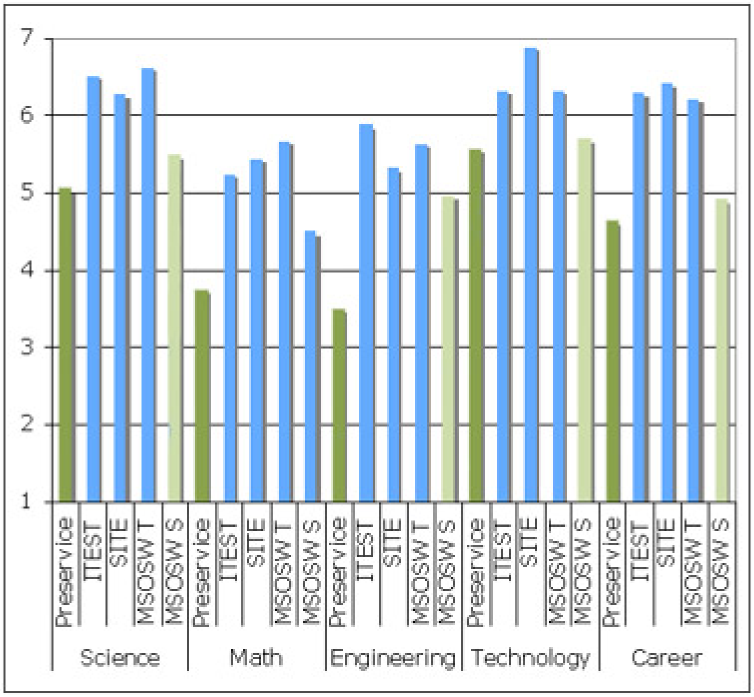

Figure 1. Semantic perceptions of five groups toward STEM content and careers.

Contrasts Between Preservice Teachers and Middle School Students

Effect sizes (Cohen's *d*) for middle school students versus preservice teacher candidates were calculated by subtracting the mean of the second from the first and dividing the result by the pooled standard deviation (as in Cohen, 1988). As shown in Table 2, effect sizes were all positive, illustrating the general tendency of the middle school students in this baseline data sample to be more positive in their perceptions of STEM than were the preservice teachers.

In increasing order of magnitude, the effect sizes for each of the STEM areas measured was .11 for Technology, .18 for Careers in STEM, .34 for Math, .48 for Science, and .95 for Engineering. These effect sizes fall in the range of small to large according to the guidelines provided by Cohen (1988) of .2 = small, .5 = moderate, and .8 = large. This trend toward lower dispositions among preservice teachers (EC – 8) compared to middle school students (similar to students many preservice educators would soon be teaching) was surprising to the research team, especially considering the fact that effect sizes beyond .3 are generally considered to be of sufficient magnitude to be educationally meaningful (Bialo & Sivin-Kachala, 1996). This exploratory finding prompted the larger scale replication study described in the following section.

Table 2
Effect Size Contrasts (Cohen's d*) in Perceptions of Middle School Students Versus Preservice Teacher Educators Toward STEM Content and Careers (2009 data, Standard Deviation Units)*

Scale	Group	*N*	Mean	*SD*	Effect Size (Cohen's *d*)
Science	Preservice teachers	58	5.04	1.42	.48
	MSOSW students	60	5.48	1.17	
	Pooled	118		1.30	
Math	Preservice teachers	58	3.73	1.53	.34
	MSOSW students	60	4.49	1.67	
	Pooled	118		1.60	
Engineering	Preservice teachers	58	3.49	1.37	.95
	MSOSW students	60	4.94	1.68	
	Pooled	118		1.53	
Technology	Preservice teachers	58	5.56	1.02	.11
	MSOSW students	60	5.69	1.33	
	Pooled	118		1.18	
Career	Preservice teachers	58	4.62	1.56	.18
	MSOSW students	60	4.91	1.58	
	Pooled	118		1.57	

Year 2 Replication Study (2009-2010 Treatment School Year)

During Year 2 of the MSOSW project, pretest data were gathered from 772 treatment and comparison group middle school students in the fall of 2009. These students were targeted for MSOSW activities during 2009-2010. Of these, 501 were from treatment schools and at the sixth- or seventh-grade levels where baseline STEM disposition data had been obtained the previous spring. These 501 middle school students were the focus of the replication (Year 2) findings reported in this section. They were from eight sites in Louisiana, Maine, Texas and Vermont and contributed .

In spring 2010 STEM disposition data were gathered from 30 elementary/middle school preservice teachers in a Midwestern U.S. university technology integration course. These students were a convenience sample consisting of two of nine sections of this course typically offered each semester. Primarily second year (sophomore) or third year (junior) teacher preparation candidates are enrolled in this required course, offered at the beginning of the methods sequence. As in the 2009 sample, teacher candidates typically have completed either one science, math, or technology-specific methods course or none prior to enrolling in this class.

In June 2010, a convenience sample of 15 STEM education professionals attending the International Society for Technology in Education (ISTE) 2010 annual conference completed STEM disposition surveys. This group represented a small proportion (< 1 %) of the STEM education professionals in attendance at the conference. Respondents had self-selected a specific presentation reporting findings from having middle school students monitor vampire (standby) power.

Descriptive statistics of the survey results for these three groups are shown in Table 3.

Table 3
Descriptive Statistics for 2009-2010 Samples of STEM Semantics Perception Data

Scale	Group	*N*	Mean	*SD*
Science	Preservice Teachers 2010	30	5.08	1.63
	ISTE conference attendees 2010	15	6.08	1.14
	MSOSW students ’09-‘10 Pretest	501	5.40	1.45
Math	Preservice Teachers 2010	30	3.70	1.63
	ISTE conference attendees 2010	15	4.88	1.50
	MSOSW students ’09-‘10 Pretest	470	4.70	1.70
Engineering	Preservice Teachers 2010	30	3.95	1.36
	ISTE conference attendees 2010	15	5.51	1.07
	MSOSW students ’09-‘10 Pretest	462	4.70	1.72
Technology	Preservice Teachers 2010	30	5.88	1.50
	ISTE conference attendees 2010	15	6.15	.95
	MSOSW students ’09-‘10 Pretest	466	5.60	1.64
Career	Preservice Teachers 2010	30	4.87	1.43
	ISTE conference attendees 2010	15	5.87	1.59
	MSOSW students ’09-‘10 Pretest	473	5.10	1.54

Note: Scale scores based on incomplete ratings were not included in descriptive statistics, That is, if a respondent failed to indicate a preference for one or more of the adjective pairs, then the entire scale of incomplete data for that individual was not used in the computations.

Replication Findings: Dispositions of Students vs. STEM Professionals

As shown graphically in Figure 2, after combining the project Year 1 (spring 2009) baseline data from Table 1 with the project Year 2 (fall 2009-spring 2010) data gathered from new samples of preservice teachers, middle school students, and STEM education professionals (see Table 2), the replication samples aligned well with those gathered from the previous project year, in each respective category. This alignment is noteworthy since a new group of subjects were in each category of sampling group during the second (2009-2010) year of the project. Color coding for student data (preservice university candidates and middle school students) illustrates that in the areas of science, mathematics, engineering, and STEM as a career, students appear to have had less positive dispositions than did the STEM education professionals.

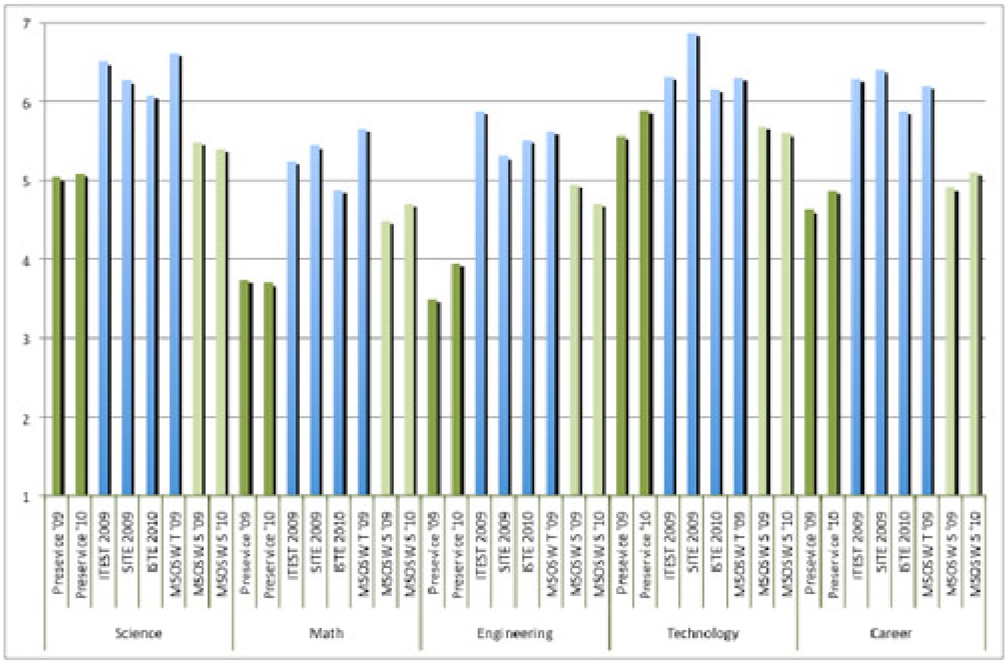

Figure 2. Semantic perceptions of eight groups toward STEM content and careers (2009-2010 data).

Formal Comparisons Between Students and STEM Education Professionals

In order to further analyze differences between the perceptions of students toward STEM versus the perceptions of professional educators toward STEM, an independent samples *t*-test procedure was conducted for each STEM area using the mean disposition for each sample as a representative data point. This conservative procedure gave the same weighting of 1 data point to the 501 middle school students and the 30 preservice teachers, for example, and resulted in just 4 data points for each of the groups of students and education professionals.

As shown in Table 4, the combined group of STEM education professionals was found to be significantly different from the aggregate group of students (including middle school students and preservice teachers) in all five areas: science (p = .001), STEM careers (p = .001), technology (p = .006), mathematics (p = .009), and engineering (p = .010). The STEM education professionals had more positive dispositions than did students in every case. These finding were anticipated by the researchers, and they reconfirmed the earlier baseline data analysis findings (Tyler-Wood et al., 2010) of (a) the measurement ability (discriminant validity) of the STEM Semantics Survey and (b) the upper bound (group mean for STEM education professionals) toward which students engaged in STEM projects and activities might be projected to rise.

Table 4
Comparisons Between Students and STEM Education Professionals on STEM Semantics Survey Scales – Using Baseline and Replication Data Samples Drawn Across Two Years (2009 and 2010)

Scale	Group	*n*	Mean	*SD*	Sig.
Science	Students	4	5.25	.22	.001
	STEM Professionals	4	6.37	.24	
	Total	8	5.81	.63	
Math	Students	4	4.16	.52	.009
	STEM Professionals	4	5.30	.33	
	Total	8	4.73	.73	
Engineering	Students	4	4.27	.67	.010
	STEM Professionals	4	5.58	.23	
	Total	8	4.92	.84	
Technology	Students	4	5.68	.14	.006
	STEM Professionals	4	6.41	.31	
	Total	8	6.05	.45	
STEM Career	Students	4	4.88	.20	.001
	STEM Professionals	4	6.19	.23	
	Total	8	5.53	.73	

Note: Students = MSOSW grade 6-8 students 2009 and 2010, preservice teachers 2009 and 2010; Professionals = ITEST 2009 participants, SITE 2009 participants, ISTE 2010 participants, and MSOSW teachers 2009.

Dispositions of Preservice Teachers versus Middle School Students

As shown in Figure 2, the dispositions of the preservice teachers in the various 2009 and 2010 samples tended to be lower than those of middle school students in all areas except technology. Independent samples *t*-test analyses were conducted to determine if these differences were likely to have occurred by chance. As shown in Table 5, the group mean scores of each 2009 or 2010 sample of middle school students ($n = 2$), were contrasted as data points with the group mean scores for preservice educator samples ($n = 2$) gathered during the same time frame. Significant ($p < .05$) differences were found for Science ($p < .02$), Math ($p < .02$), and Engineering ($p < .05$), but not for Technology ($p = .70$, *ns*). The data in Table 5 also indicate that the differences between the dispositions of preservice teachers and middle school students was not sufficiently large to reject the possibility that it occurred by chance ($p = .24$, *ns*) in the case of dispositions toward STEM Careers. Contrasts between middle school students and preservice educators are graphically displayed in Figure 3.

Table 5
Group Mean Comparisons for Middle School Students vs. Preservice Teachers on STEM Semantics Survey Scales – Using Baseline and Replication Data Samples Drawn Across Two School Years

Scale	Group Mean Averages	*n*	Mean	*SD*	Sig.
Science	Preservice Teachers	2	5.06	.028	.02
	Middle School Students	2	5.44	.057	
	Total	4	5.25	.222	
Math	Preservice Teachers	2	3.71	.021	.02
	Middle School Students	2	4.60	.148	
	Total	4	4.16	.515	
Engineering	Preservice Teachers	2	3.72	.325	.05
	Middle School Students	2	4.82	.170	
	Total	4	4.27	.669	
Technology	Preservice Teachers	2	5.72	.226	.70
	Middle School Student	2	5.65	.064	
	Total	4	5.68	.142	
STEM Career	Preservice Teachers	2	4.75	.177	.24
	Middle School Students	2	5.01	.134	
	Total	4	4.88	.197	

Note: Middle School Students = MSOSW grade 6-8 students 2009 and 2010; Preservice Teachers = university preservice teachers 2009 2010.

Gender Contrasts for Middle School Students

Middle school student data gathered during the 2009-2010 school year were disaggregated for further analysis based on gender. Descriptive statistics for *n* = 86 males and *n* = 84 females who (a) participated in MSOSW activities, (b) completed both pre- and posttest surveys, and (c) were able to be positively identified as matching pretest score with post, are provided in Table 6. Posttests were administered during the last month of the school year at each school site, in May and June of 2010.

As shown in Figure 4, females participating in MSOSW activities appeared more positive in their STEM dispositions during the 2009-2010 school year in several areas, while male middle school students remained largely unchanged. In the area of perception of technology and of perception of mathematics, females as a group approached or exceeded the ES = .3 criterion normally accepted for the point at which the magnitude of an intervention becomes educationally meaningful (Bialo & Sivin-Kachala, 1996). The last column of Table 6 indicates that in the area of Technology (ES = .40, *p* = .02) the gains exhibited by the females were unlikely to have occurred by chance, while for the males, the small changes that occurred were likely to have occurred by chance in all five measured areas (Male ES range = -0.04 through 0.15; probability range = 0.41 through 0.90).

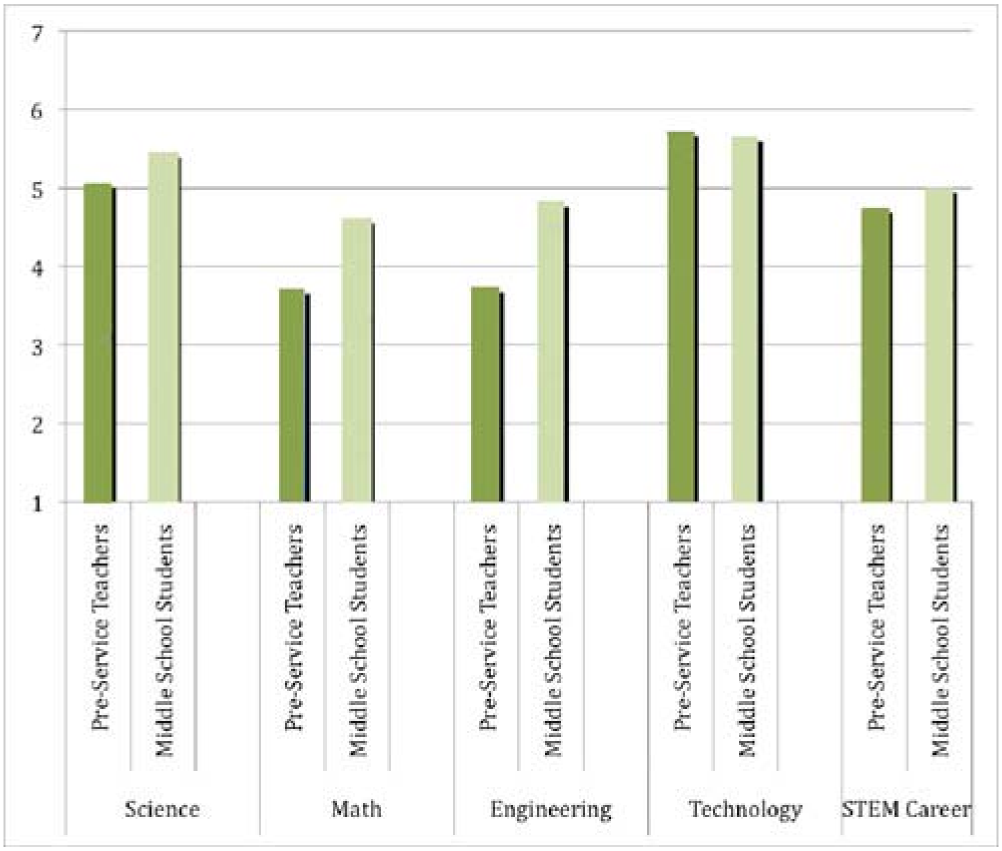

Figure 3. STEM Semantics dispositions of middle school students versus preservice teachers using baseline and replication data samples drawn across two school years.

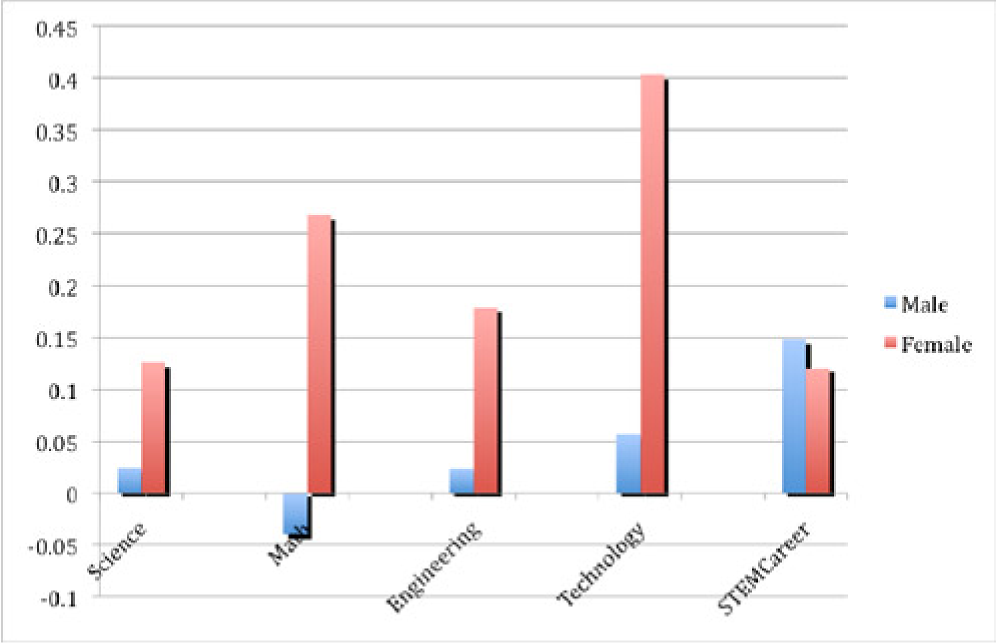

Figure 4. Pre-post gains (effect size) for MSOSW middle school males vs. females, 2009-2010.

Table 6
Group Mean Comparisons for Male vs. Female Middle School Students on STEM Semantics Survey Scales (2009-2010 School Year)

Scale		**Mean**	***N***	***SD***	**ES**	**Paired *t***	**Signif**
Male Students							
Science	Pre	5.32	77	1.31	0.02	0.139	0.89
	Post	5.35	77	1.52			
Math	Pre	4.81	72	1.51	-0.04	-0.226	0.822
	Post	4.75	72	1.63			
Engineering	Pre	4.89	70	1.52	0.02	0.124	0.902
	Post	4.93	70	1.82			
Technology	Pre	5.66	71	1.44	0.06	0.354	0.724
	Post	5.74	71	1.59			
STEM Career	Pre	5.02	77	1.50	0.15	0.833	0.408
	Post	5.24	77	1.69			
Female Students							
Science	Pre	5.07	68	1.44	0.13	0.657	0.514
	Post	5.25	68	1.69			
Math	Pre	4.50	71	1.56	0.27	1.385	0.171
	Post	4.91	71	1.77			
Engineering	Pre	4.66	67	1.40	0.18	0.79	0.433
	Post	4.91	67	1.83			
Technology	Pre	5.22	70	1.60	0.40	2.333	0.023
	Post	5.86	70	1.63			
STEM Career	Pre	5.03	73	1.45	0.12	0.632	0.53
	Post	5.21	73	1.80			

Comparisons of STEM Semantics Survey Indicators With Other Student Attitudes and Dispositions

A 2010 analysis of the of the CAQ scales for the MSOSW project data reported in this paper yielded scale reliabilities ranging from .73 to .85 (Mills, Wakefield, Najmi, Surface, Christensen, & Knezek, in press). According to the guidelines provided by DeVellis (1991), these fall in the range of “respectable to “very good.”

Descriptive statistics, effect size magnitude indicators of pre-post gains, and paired *t* results for CAQ scales from MSOSW data, are listed in Table 7. As shown in Appendix B and graphically displayed in Figure 5, the CAQ trended toward female rather than male technology attitude and learning disposition gains, mirroring results from the STEM Semantics Survey. These similar conclusions drawn from the well-established, Likert-style CAQ, provide additional evidence to validate the STEM Semantics Survey findings presented in Table 6. Note that the negative effect sizes (pre-post) for Attitude Toward School (School) and Self-Concept probably reflect a time-of-year response effect that the authors have commonly found in studies with a beginning-to-end-of-school-year measurement time frame.

Even within this end-of-school year (May-June) typical decline in student attitudes, the females dropped less than the males dropped. This trend is consistent with previous studies by the authors indicating that girls generally have more positive attitudes toward school than do boys (Christensen, Knezek, & Overall, 2005), and also aligns with recent findings from the Millennium Cohort Study in the United Kingdom that boys are twice as likely as girls to say they dislike school even at age 7 (Dix, 2010).

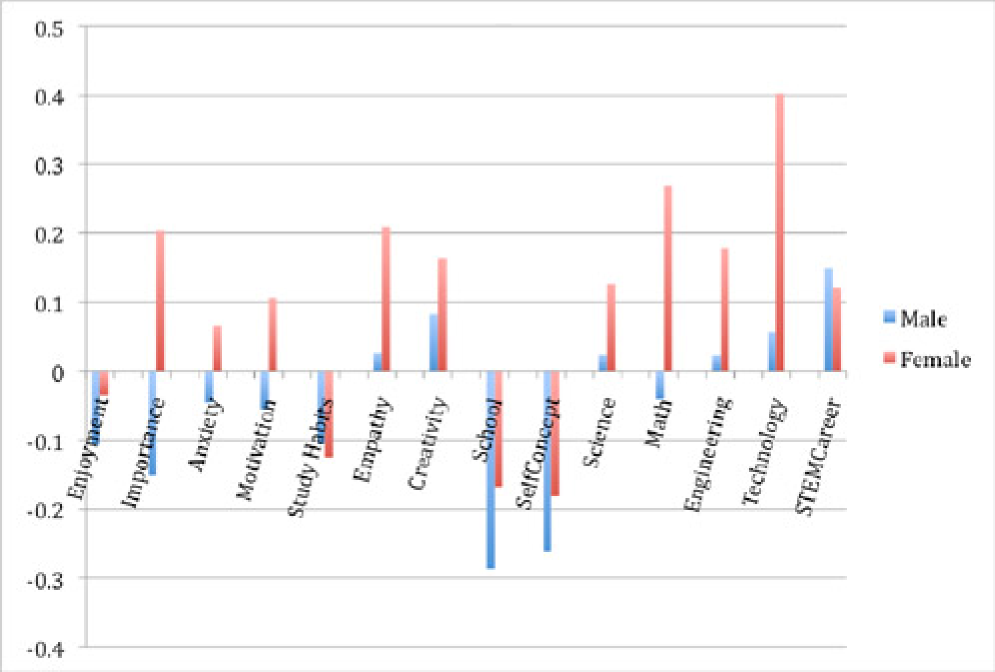

Figure 5. Pre-post gains in effect size (Cohen's *d*) standard deviation units for MSOSW middle school female vs. male students, CAQ and STEM Semantics Surveys, 2009-2010.

Gender Equalization of Perceptions of Technology

As shown in Figures 6 and 7, in the area of positive perceptions of technology, females appear to have gained to the point where they caught up with the boys over the course of the 2009-2010 MSOSW project year. Specifically in the area of semantic perception of technology as assessed by the STEM Semantics Survey, females had significant pre-post gain (p = .02, ES = .40) while the males did not (p = .72, ES = .06). A closer examination (see Figure 6) reveals that the females began with lower perceptions of the technology than did males, but ended the school year of activities at least equal to or perhaps more positive toward technology than did their male counterparts. Figure 7 reveals a similar pattern for girls versus boys on the CAQ scale, Computer Importance. Girls were initially lower that the boys on this index, but ended the year with group mean values comparable to the boys.

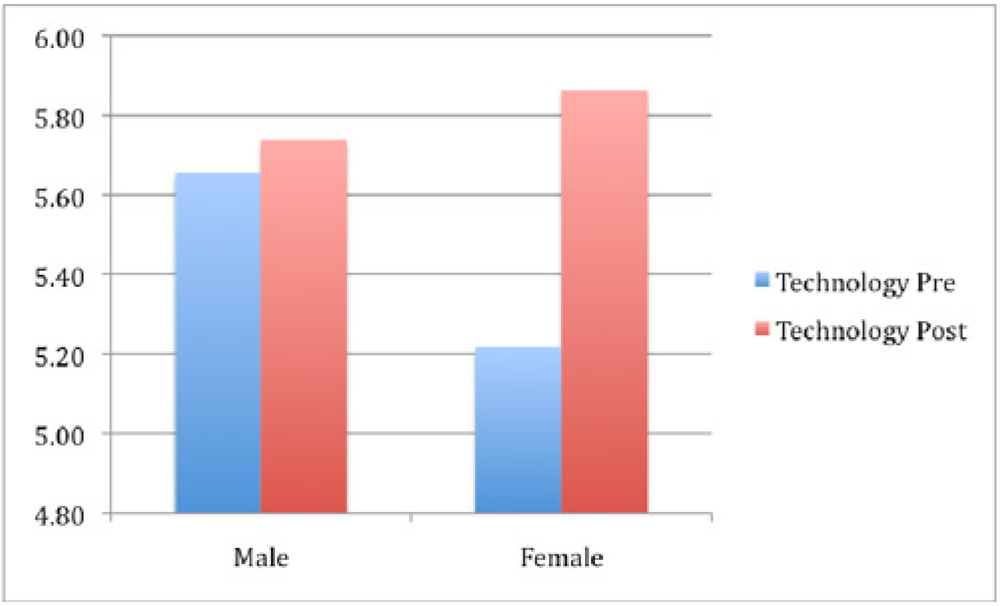

Figure 6. Comparison of male vs. female pre-post trends for Semantic Differential Perceptions of Technology.

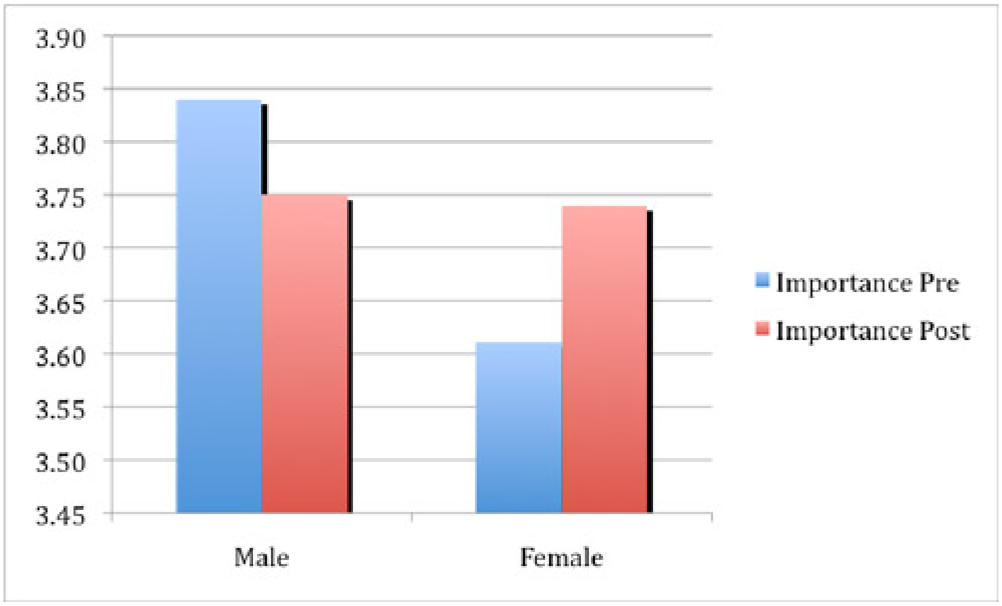

Figure 7. Likert Scale (Computer Importance) pre-post trends in female vs. male perceptions of computers.

Discussion and Implications of Findings

From a high-level perspective, the positive dispositions found for the practicing science and technology educators, principal investigators and evaluators, and technology infusion faculty in this study can be viewed as a target level toward which one might hope the middle school students and the preservice teachers might evolve. Educational leaders might target the high STEM dispositions of those professionals currently in STEM education careers as principal investigators or evaluators, technology educators, or teachers, as the level to which we hope the students might rise. If the perceptions of students move in the direction of the perceptions of STEM professionals over time, then this change in perception can be considered a success. Even for future K-8 school teachers who are not expected to become STEM specialists, one can anticipate that a more positive aura (semantic perception) about STEM topics and careers would be a positive occurrence in that this aura would tend to be transferred to elementary school students.

The semantic differential instrument called the STEM Semantics Survey, has special properties that make it attractive for longitudinal studies of a single group, as well as for snapshot analyses across multiple groups. The instrument was refined from earlier work (see Knezek et al., 2009, and Tyler-Wood et al., 2010, for more detailed information). Since each of the adjective pairs is presented (in a counterbalanced fashion) for every target item, direct comparisons of perception of science to perception of math or engineering, for example, are meaningful. Figure 2 illustrates that MSOSW middle school students began the 2009-2010 school year with low perceptions of math and engineering (compared to science) and highly positive perceptions of technology.

This instrument’s special characteristics are believed to provide a solid foundation for more detailed study of complex societal questions such as the following:

- Is the current low level of interest in STEM careers among U.S. students a generational issue, or the result of lack of exposure to activities that would stir students’ interests, either inside or outside of school?
- Did the STEM-interested educators already possess high dispositions as young children and were high STEM disposition children the ones who persisted to become positive-disposition STEM teachers?

The similarity of perceptions of the middle school students to those of the preservice teachers, combined with the contrast in the perceptions of teacher educators and NSF project leaders and evaluators, causes us as researchers to wonder why and whether this is a new phenomenon or if it may have always been this way. Further research is needed to answer these kinds of questions. The replication portion of this study has simply confirmed that the contrasts between STEM education professionals and middle school students and university preservice teachers are large and consistent.

The different pre-post treatment year effects found for female versus male middle school students in this study reinforces the need to disaggregate the data for detailed analyses. Indications based on 2009-2010 school year findings are that (a) MSOSW project activities have been more successful in fostering positive dispositions toward STEM in females than in males, and (b) the effect in the area of dispositions toward technology has been to raise the girls to a level where they have positive dispositions toward technology that are comparable to the boys' dispositions. The finding that the girls had pretest dispositions toward technology less positive than the boys' dispositions is consistent with previous findings by Weinburgh (1995) and others.

The data gathered for this study are from convenience samples, and the findings are, therefore, not necessarily representative of the USA as a whole. Expected generalizability is especially limited for the preservice teachers in this study, because they are sampled from a group in one state, primarily northern Texas. Generalizability is perhaps better for the middle school students. They are sampled from five states in the USA—Louisiana, Hawaii, Maine, Texas, and Vermont—and can be expected to be representative of the country. Generalizability is believed to be acceptable for the collective group of STEM education professionals, because they are represented in the samples of data collected by five different sets of STEM-related entities, and have respondents within each entity hailing from many different U.S. states.

Conclusions

An instrument created to assess perceptions of STEM disciplines and interest in STEM careers has provided baseline data and first-treatment-year pretest replication data sufficient to demonstrate that large gaps exist between the perceptions of science, technology, engineering, and mathematics held by middle school students versus those of their teachers. Furthermore, the perceptions of university preservice teachers are more similar to the middle school students than to the perceptions of the MSOSW project teachers, while the perception of technology education faculty are more like those of the project teachers and National Science Foundation project directors and evaluators, and ISTE technology educators. Further research is needed to determine whether these gaps are the result of generational differences or perhaps due to the matriculation of teachers-to-be who have high STEM dispositions into positions of sustaining (longlasting) teacher roles. The latter would imply that this is not a new problem to be addressed, as was contended by Watters et al. (1995). The former would imply that this may be a new problem arising with the millennial generation. If the problem is specific to the millennial generation, it is important to address the issue for the sake of sustaining high standard-of-living societal goals.

Analysis of middle school student data disaggregated by gender indicate that (a) girls had dispositions toward technology less positive than boys at the time of the 2009-2010 pretest, but (b) girls' dispositions toward technology had risen to a point where they were on par with the boys by the time of the posttest. These data imply that the MSOSW project activities may be especially effective for girls.

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Appendix A

STEM Semantics Survey

Gender: M / F

This five-part questionnaire is designed to assess your perceptions of scientific disciplines. It should require about 5 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

ID: _________________ **School:**_____________	Use the assigned ID or the year and day of your birthday (ex: 9925 if born on the 25th day of any month in 1999.

Instructions: Choose one circle between each adjective pair to indicate how you feel about the object.

To me, SCIENCE is:

1.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
2.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
3.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
4.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
5.	boring	①	②	③	④	⑤	⑥	⑦	interesting

To me, MATH is:

1.	boring	①	②	③	④	⑤	⑥	⑦	interesting
2.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
3.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
4.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
5.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot

To me, ENGINEERING is:

1.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
2.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
3.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
4.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
5.	boring	①	②	③	④	⑤	⑥	⑦	interesting

To me, TECHNOLOGY is:

1.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing
2.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
3.	boring	①	②	③	④	⑤	⑥	⑦	interesting
4.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
5.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane

To me, a CAREER in science, technology, engineering, or mathematics (is):

1.	means nothing	①	②	③	④	⑤	⑥	⑦	means a lot
2.	boring	①	②	③	④	⑤	⑥	⑦	interesting
3.	exciting	①	②	③	④	⑤	⑥	⑦	unexciting
4.	fascinating	①	②	③	④	⑤	⑥	⑦	mundane
5.	appealing	①	②	③	④	⑤	⑥	⑦	unappealing

Thank you for your time.
STEM v. 1.0 by G. Knezek & R. Christensen 4/2008

Appendix B
Male vs. Female Pre-Post Gains on CAQ Scales, 2009-2010
(Paired Samples Statistics)

		Mean	***N***	***SD***	**ES**	**Paired I**	**Sig. (2-tailed)**
Male Students							
Enjoyment	Pre	4.20	74	0.52	-0.11	-0.90	0.37
	Post	4.14	74	0.62			
Importance	Pre	3.84	74	0.60	-0.15	-0.91	0.37
	Post	3.75	74	0.64			
Anxiety	Pre	4.25	74	0.71	-0.05	-0.44	0.66
	Post	4.22	74	0.65			
Motivation	Pre	3.62	73	0.64	-0.06	-0.55	0.58
	Post	3.58	73	0.67			
Study Habits	Pre	3.63	73	0.58	-0.11	-0.95	0.35
	Post	3.57	73	0.65			
Empathy	Pre	3.71	73	0.70	0.03	0.33	0.74
	Post	3.73	73	0.69			
Creativity	Pre	3.67	73	0.50	0.08	0.69	0.50
	Post	3.71	73	0.63			
School	Pre	3.01	74	0.80	-0.29	-2.36	0.02
	Post	2.78	74	0.86			
Self Concept	Pre	4.04	74	0.77	-0.26	-1.89	0.06
	Post	3.84	74	0.88			
Science	Pre	5.32	77	1.31	0.02	0.14	0.89
	Post	5.35	77	1.52			
Math	Pre	4.81	72	1.51	-0.04	-0.23	0.82
	Post	4.75	72	1.63			
Engineering	Pre	4.89	70	1.52	0.02	0.12	0.90
	Post	4.93	70	1.82			
Technology	Pre	5.66	71	1.44	0.06	0.35	0.72
	Post	5.74	71	1.59			
STEM Career	Pre	5.02	77	1.50	0.15	0.83	0.41
	Post	5.24	77	1.69			
Female Students							
Enjoyment	Pre	4.06	69	0.51	-0.03	-0.27	0.79
	Post	4.04	69	0.50			
Importance	Pre	3.61	69	0.63	0.20	1.50	0.14
	Post	3.74	69	0.62			
Anxiety	Pre	4.15	69	0.59	0.07	0.48	0.63
	Post	4.19	69	0.62			
Motivation	Pre	3.65	69	0.54	0.11	0.89	0.38

	Post	3.71	69	0.47			
Study Habits	Pre	3.81	69	0.56	-0.12	-1.06	0.30
	Post	3.74	69	0.48			
Empathy	Pre	4.31	69	0.50	0.21	2.18	0.03
	Post	4.41	69	0.46			
Creativity	Pre	3.66	69	0.50	0.16	1.19	0.24
	Post	3.74	69	0.50			
School	Pre	3.45	69	0.78	-0.17	-1.64	0.11
	Post	3.32	69	0.80			
Self Concept	Pre	4.13	69	0.66	-0.18	-1.30	0.20
	Post	4.01	69	0.85			
Science	Pre	5.07	68	1.44	0.13	0.66	0.51
	Post	5.25	68	1.69			
Math	Pre	4.50	71	1.56	0.27	1.39	0.17
	Post	4.91	71	1.77			
Engineering	Pre	4.66	67	1.40	0.18	0.79	0.43
	Post	4.91	67	1.83			
Technology	Pre	5.22	70	1.60	0.40	2.33	0.02
	Post	5.86	70	1.63			
STEM Career	Pre	5.03	73	1.45	0.12	0.63	0.53
	Post	5.21	73	1.80			