Science Education International
Vol. 24, Issue 1, 2013, 98-123

Impact of environmental power monitoring activities on middle school student perceptions of STEM

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ABSTRACT: Middle school is a crucial stage in student development as students prepare for a fast changing future. The science, technology, engineering and mathematics (STEM) skills that students acquire in middle school lay the foundation for a successful career in STEM. Moreover, most STEM occupations require competencies in science, math and logical thinking prior to engagement in problem solving. Therefore, it is vital to prepare and develop interest in middle school students to participate in the future STEM workforce. This study examines the impact of hands-on authentic projects on middle school students' STEM content knowledge and perceptions. The participants for the study were 246 middle school students (Grades 6, 7, and 8) from six schools in the states of Texas, Louisiana, Maine and Vermont in the United States (U.S.). Employing a quasi-experimental design, the students who participated in the project activities were measured on their STEM knowledge and dispositions before and after project participation. The findings indicate that middle school students who participated in standby power monitoring activities not only reported gains in their STEM content knowledge, but also showed an improvement in their creative tendencies and their perceptions about STEM subjects and careers. This increase in STEM perceptions was more pronounced for female middle school students than for male students. The results of the study suggest that carefully designed project-based activities that encourage inquiry-based learning can be very effective at the middle school level.

KEY WORDS: middle school, STEM perceptions, technology

INTRODUCTION

In the United States as in many nations, efforts are being made to improve science, technology, engineering and mathematics (STEM) education and make it a national priority to strengthen the nation's position in discovery and innovation globally (The White House, 2009). The skills in STEM areas that students acquire in middle school lay the foundation for a successful career in STEM (Woolley, Strutchens, Gilbert, & Martin, 2010). Most STEM occupations require competencies in science, mathematics

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and logical thinking to allow problem solving. Middle school is a crucial stage in student development as students prepare for a fast changing future (George, Stevenson, Thomason, & Beane, 1992). Therefore, it is vital to prepare and develop interest in middle school students to participate in the future STEM workforce. The current study is important as it explores middle school students' dispositions towards STEM subjects and examines the impact of project-based learning on students' STEM content knowledge as well as perceptions of STEM content and career perceptions. Gender differences and implications of findings are also discussed.

CONCEPTUAL FRAMEWORK

This study is part of a three-year National Science Foundation (NSF) Innovative Technology Experiences for Students and Teachers (ITEST) project, which aims to focus pre-teen interest in activities to foster learning about energy consumption in students' homes and communities, and to incubate interests and knowledge about STEM majors and careers. The theoretical foundation of the project is referred to as *productivity-centered service-learning* (IITTL, 2010), a term coined by a member of the project research team to describe: a) the multiple theory basis formed from the theories of constructivist learning (Bentley, E. Ebert, & S. Ebert, 2007; Lave & Wenger, 1991; Means, 2003), b) theories that bear on the intersection of technology and real-world scientific inquiry in K-8 classrooms (Bentley et al., 2007; Bevan & Semper, 2006; Crane, Nicholson, Chen, & Bitgood, 1994; Douglas, 2006; Glock, Meyer, & Wertz, 1999), and c) game and simulation-based learning theory (Aldrich, 2005; Gibson, Aldrich, & Prensky, 2006; Gibson, Grasso, & Bongard, 2006; Klein, 1995; Pfeiffer & Ballew, 1988; Prensky, 2001; Shaffer, 2005).

Inquiry-based learning has been strongly encouraged by most science educators because students are provided with opportunities to ask questions, explore, plan, and most importantly, construct new knowledge and reflect on their learning (Chen & Howard, 2010; Shedletzky & Zion, 2005). Project-based learning, where students involved in inquiry work on real-world projects and are encouraged to form their own conclusions (Savery, 2006), can narrow the gap between academics and the actual practice of the profession (Verma, Dickerson, & McKinney, 2011). When activities such as standby power monitoring in the current study integrate science and mathematics, it helps develop interest in both content areas (Sherrod, Dwyer, & Narayan, 2009). Such hands-on activities cannot only improve achievement but also develop communication, critical thinking and problem-solving (Verma et al., 2011).

In Europe as well as the U.S., an alarming decline in student interest in STEM has been noted (Rocard et al., 2007). A European Commission panel of experts has indicated that interest in STEM is directly related to how STEM is taught in schools. The European Commission has recommended the use of inquiry-based methods such as those featured in the MSOSW project, that have been judged to be effective in engaging students in STEM learning (Healey, 2005). The European Commission indicates that inquiry-based science education (IBSE) can improve science learning at both primary and secondary levels by increasing students' interest, from the weakest to the most capable student (Rocard et al., 2007).

EDUCATIONAL SIGNIFICANCE: WHY MIDDLE SCHOOL?

According to many sources, STEM career intervention and enrichment plans should be initiated well before the high school years (George et al., 1992). As education and popular perception of technology and engineering standards evolve, there is an increased awareness of the need for STEM literacy within society. STEM literacy fosters intelligent participation in public socio-scientific and ethical decisions, which direct the future of engineering and technology (Gorham, 2002; Stiller, De Miranda, & Whaley, 2007). Many studies focus on factors affecting students' attitudes towards science such as the influence of teachers, parents and peers on students' science attitudes (George, 2006; Rodrigues, Jindal-Snape, & Snape, 2011; Sevinc, Ozmen, & Yigit, 2011). However, there is a need for more studies evaluating the effectiveness of authentic hands-on projects in STEM content areas.

MSOSW PROJECT

The Middle Schoolers Out to Save the World (MSOSW) project was designed to develop middle school students' interest in STEM content areas and to prepare students for the STEM workforce. The ongoing project aims to direct middle school student enthusiasm for hands-on activities, and to guide students to solve real-world problems. Students in this study are trained by their teachers to use energy monitoring equipment to monitor and audit power consumption by consumer electronic devices in their homes and communities.

Standby power (also called *Vampire Power*) is the electricity consumed by many appliances when they are plugged in but "turned off" (U.S. Department of Energy, 2011). Many appliances consume some electricity while not performing any useful function. The U.S. Department of Energy has estimated that over the lifetime of a typical home appliance, 70% of the power consumed will be when the appliance is turned off (U.S. Department of Energy, 2011). Televisions, game consoles, home computers and microwaves are a few of the appliances that commonly consume standby power. With the help of their teachers, sixth and seventh grade students learn to measure the vampire power use of various appliances in the students' homes. After measuring standby power, students gather their data together with their classmates in spreadsheet projections to explore energy conservation plans that can lower a family's monthly electric bill and reduce the greenhouse gas emissions that contribute to global warming. Students share their results with other middle school students from across the U.S.

These MSOSW project activities are grounded in practices based on inquiry-based learning, and project-based learning to make the learning experience more student-centered. Guided by inquiry-based learning practices, the MSOSW project activities (standby power monitoring, projecting global impact on climate) are designed to encourage students to question, think critically and solve authentic problems (Savery, 2006). Project-based learning practices are also included to organize the MSOSW activities around achieving a shared project goal. In both inquiry-based learning and project-based learning, the teacher plays a role of a facilitator providing students with guidance and feedback. The students in the MSOSW activities are provided with details about the project. Whenever students encounter problems, these problems are treated as "teachable moments" (Savery, 2006).

RESEARCH QUESTIONS

Four research questions with corresponding hypotheses are addressed in this study.

1. What is the effect of the Middle Schoolers Out to Save the World (MSOSW) project activities on middle school students' STEM content knowledge?

> Null Hypothesis: The MSOSW project activities will have no effect on middle school students' STEM content knowledge.
> Research Hypothesis: The MSOSW project activities will have a positive effect on the middle school students' STEM content knowledge.

2. What is the impact of the MSOSW project activities on middle school students' perceptions of science, technology, engineering, and mathematics?

> Null Hypothesis: The MSOSW project activities will have no impact on how the middle school students perceive the STEM content areas.
> Research Hypothesis: The MSOSW project activities will have a positive impact on how the middle school students perceive the STEM content areas.

3. What is the effect of the MSOSW project activities on the middle school students' perceptions of and/or aspirations for STEM careers?

Null Hypothesis: The MSOSW project activities will have no impact on middle school students' perceptions of and aspirations for STEM careers.
Research Hypothesis: The MSOSW project activities will have a positive impact on the middle school students' perceptions of and aspirations for STEM careers.

4. How do the male and female middle school students differ in their improvement in STEM content knowledge and perceptions after participating in the MSOSW activities?

Null Hypothesis: There will be no differences in the improvement of male and female students in their STEM content knowledge and perceptions after participating in the MSOSW activities.
Research Hypothesis: There will be differences in the improvement of male and female students in their STEM content knowledge and perceptions after participating in the MSOSW activities.

The section *Results* will focus on answering these questions.

REVIEW OF RELEVANT LITERATURE

A review of the literature on middle school students' attitudes towards science (McCoy, 2006) revealed that during the first portion of the 21st century there was a decrease in interest in science and a decrease in belief that taking science courses in school would enable students to contribute to society. Attitudes formed in middle school have a great influence on the science and mathematics courses that students take in high school (Misiti, Shrigley & Hanson, 1991). Substantiating this trend, George (2006) notes that attitudes about science positively relate to how middle school students perceive the usefulness of science. Although students value the utility of science, fewer students take STEM coursework as they move to high school. Several studies have found a significant relationship between students' attitudes towards STEM areas and their actual performance (Choi & Chang, 2009; Hammouri, 2004; Liu, 2008). Further, self-confidence in mathematics and anxiety towards mathematics (Liu, 2008) has a strong influence on students' mathematics achievement. Understanding if an intervention is effective on students' achievement in STEM areas is important because adolescent students with low mathematics achievement have lower STEM career aspirations than students with higher mathematics achievement (Choi & Chang, 2009).

The National Council of Teachers of Mathematics (NCTM) indicates that students should have a proper understanding of mathematics and know how to apply mathematics concepts. The research of Sherrod et al. (2009) shows that it is more useful when students learn mathematics integrated with other content areas such as science rather than when learning mathematics concepts in isolation. It is also important to allow students to assume the roles of scientists and mathematicians to investigate, calculate, and analyze data to solve the problems (Sherrod et al., 2009). Kesici and Erdoğan (2009) have shown that students' anxiety about mathematics can affect achievement and perceptions about mathematics ability. Creating positive experiences with mathematics, such as the project activities in this study, can help influence students perceptions about mathematics.

Several factors influence whether or not a student will decide to pursue a career in engineering. Some factors involve how social circles, including students' parents, peers, and teachers guide or influence a student's perceptions about engineering, (Fralick, Kearn, Thompson & Lyons, 2009) and achievement in STEM areas (Woolley et al., 2010). In Fralick et al. (2009)'s study on how middle school students perceive engineers and scientists, the majority of the student drawings showed the scientist as a male person wearing a lab coat. Students generally drew engineers as individuals working outdoors, doing physical actions such as building or operating machinery, rather than highlighting higher-level mental functions such as experimenting. The authors pointed out that it was not just a misconception about engineers; instead, it was a lack of basic understanding about engineering and what engineers do. More hands-on authentic activities are essential to help students understand what it entails to become an engineer. A review of engineering outreach programs emphasizes the need to introduce engineering at an earlier age.

Technology is an integral part of today's classrooms. Many research studies have shown that using computers increases student motivation and enhances the learning experience of students (Hsieh, Cho, Lui, & Schallert, 2008). Hsieh et al. (2008) suggested that computers provide more opportunities for authentic learning. In technology-enhanced environments, students are self-directed and collaboratively explore solutions for the given problem. In the study of using technology-enhanced environments, middle school students who participated showed a significant increase in their science achievement (Hsieh et al., 2008). Crucial to these active learning environments is how students perceive the use of computers for learning. A multi-year study on portable technology reported that students generally have positive attitudes towards portable devices, which may contribute to offsetting the decline in motivation that students experience in middle school years (Hill, Reeves, Grant, Wang & Han, 2003).

Gender Differences in STEM Perceptions and Achievement

Gender differences in STEM interest and achievement have been the subject of numerous discussions in scholarly literature (Choi & Chang, 2009). Although earlier studies have shown that male students perform better in STEM areas than female students, Choi and Chang (2009) observed that recent studies have shown mixed results. As Knezek, Christensen & Tyler-Wood (2011) argued, the gender gap is less of an ability gap than a gap in perceptions of science careers (Knezek, Christensen, & Tyler-Wood, 2011). Liu (2008) observed that girls had better mathematics grades on classroom tests while boys had better mathematics scores on standardized tests. This difference was attributed to the social aspect of the classroom compared to the impersonal standardized test environment. Including social aspects in science and mathematics activities may be more effective for girls. In their study of science attitudes of high school students, Quinn and Lyons (2011) found that although there was no gender difference in how students enjoyed science, boys reported enjoying science more in comparison with other content areas. Fewer than 10% of engineers in the United States are female (Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007). Many women have historically been relatively uninformed about STEM fields and many are thought to have a higher attraction to career fields perceived as being of service to society (Hirsch et al., 2007).

RESEARCH DESIGN AND METHODS

This research employed a quasi-experimental research design. The participants for the study were 246 middle school students from six schools in Louisiana, Texas, Maine and Vermont. The majority of the participants were from 7^{th} grade. Male (n = 123) and female students (n = 123) were equally represented in the sample. Data for this study were gathered as part of a larger study during the year 2010-2011. Online surveys were administered to the MSOSW students during the first months and again during the last months of a nine-month school year. A battery of instruments was used to measure knowledge of standby power, attitudes toward STEM content and careers, learning dispositions such as creative tendencies, motivation, study habits, and interest in various careers. Only the variables used in the current research are discussed here. The number of subjects involved in the examination of each research question varied widely, depending upon the number of sites that completed relevant treatments and the ability to match specific pretest records to post test records. In each case, the relevant statistical test with the greatest precision was employed. For example, a paired *t* test involving 75 students identified as pre-post matched pairs would be selected over a non-paired *t* test involving a larger group of perhaps n = 140 without IDs sufficient to produce matched pairs.

Demographic information

A demographic questionnaire was administered to assess participants' gender, grade-level and school information.

STEM dispositions and STEM career attitudes

The STEM Semantics Survey (Tyler-Wood, Knezek, Christensen, 2010) was used to measure interest in each STEM subject as well as interest in STEM careers more generally. 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, mathematics, engineering and technology. A fifth scale representing interest in a career in science, technology, engineering, or mathematics (STEM) was also created. The internal consistency ratings for the five subscales ranged from 0.88 to 0.93, which can be considered very good (DeVellis, 1991). The five scales had five items each and each item was presented as semantic adjective pairs (fascinating: mundane; exciting: unexciting, and so forth) to describe STEM dispositions and career attitudes. A copy of this survey is provided in the Appendix 1.

RESULTS

Content Knowledge

The MSOSW students gained knowledge of standby power during the 2010-2011 school year. Analysis of paired pre-post data from 246 middle school students on the National Geographic Vampire Power test (Meier, 2009) revealed that for boys ($t(122) = 5.44$, $p < .001$) and girls ($t(122) = 5.05$, $p < .001$) there was a significant gain in knowledge of standby (vampire) power sources and remedies. The effect size (Cohen's d) was 0.68 and 0.60 for boys and girls respectively. These are placed between moderate and large effect sizes according to the guidelines provided by Cohen (1988) of small = 0.2, moderate = 0.5 and large = 0.8. These effect sizes are well beyond the ES = 0.3 criterion that is normally considered educationally meaningful according to established research guidelines (Bialo & Sivin-Kachala, 1996). The gain in STEM content knowledge for male and female students is shown in Figure 1. As seen in Figure 1, both male and female students improved in their knowledge about Vampire Power.

Table 1. Pre-Post Gains in Vampire-Power scores for 2010-11 MSOSW Students: Grades 6-8

Scale	*Group*	*n*	*M*	*SD*	*t*	*Sig.*	*ES*
Males	Pretest	123	3.58	1.66	5.44	.001	.68
	Post Test	123	4.76	1.79			
Females	Pretest	123	3.84	1.71	5.05	.001	.60
	Post Test	123	4.92	1.89			

Note. N =123

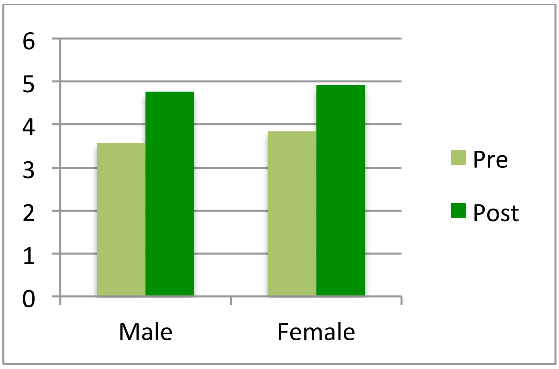

Figure 1. Pre-post gains in vampire power knowledge by MSOSW students 2010-11.

STEM Dispositions: Perceptions of Science, Technology, Engineering, and Mathematics

Analyses have confirmed that more positive STEM dispositions emerged among MSOSW participants in selected areas. Overall, based on identifiable matched pairs pre-post data from 170 middle school students from four MSOSW treatment schools, dispositions became more positive in all five areas measured by the STEM Semantic Survey (see Table 2). The likelihood of this occurrence by chance is quite small (binominal one-tailed probability, p = .03), indicating that STEM dispositions in general became more positive during MSOSW activities. Semantic perceptions of technology increased significantly ($p < .05$) between pretest and post test measurement times.

Table 2. Pre-Post Changes in Middle School STEM Dispositions

		n	*M*	*SD*	*ES*	*Paired t*	*DF*	*Sig.*
Science	Pre	145	5.20	1.37	0.07	-.581	144	.562
	Post	145	5.30	1.59				
Mathematics	Pre	143	4.65	1.54	0.11	-.871	142	.385
	Post	143	4.83	1.70				
Engineering	Pre	137	4.78	1.46	0.08	-.672	136	.502
	Post	137	4.92	1.82				
Technology	Pre	141	5.44	1.53	0.23	-2.00	140	.047*
	Post	141	5.80	1.60				
STEM Career	Pre	150	5.02	1.47	0.12	-1.04	149	.300
	Post	150	5.22	1.74				

Note: * $p < 0.05$

The pre-post findings on STEM dispositions from one MSOSW school (see Table 3) showed that students became significantly more positive on the 5-item semantic differential scale of "*To me, math is*" over the course of the school year, which included MSOSW project activities. Students came to see mathematics as more appealing, more exciting, and less boring. The sixth grade students exhibited large (ES = .93) (Cohen, 1988) pre-post gains in their semantic perceptions of mathematics (see Figure 2). Such a gain is very unlikely to have occurred by chance ($p < 0.005$). This emergent finding raises an important question as to precisely what combination of activities and motivations resulted in such large gains at this site. Further research is planned in this area.

Table 3. 6th Grade Semantic Perception of Mathematics

Scale	*Group*	*M*	*SD*	*Paired t*	*Sig.*	*ES*
Mathematics	Pretest	3.26	2.04	-2.92	.005	.93
	Post Test	4.72	1.10			

Note: N = 19

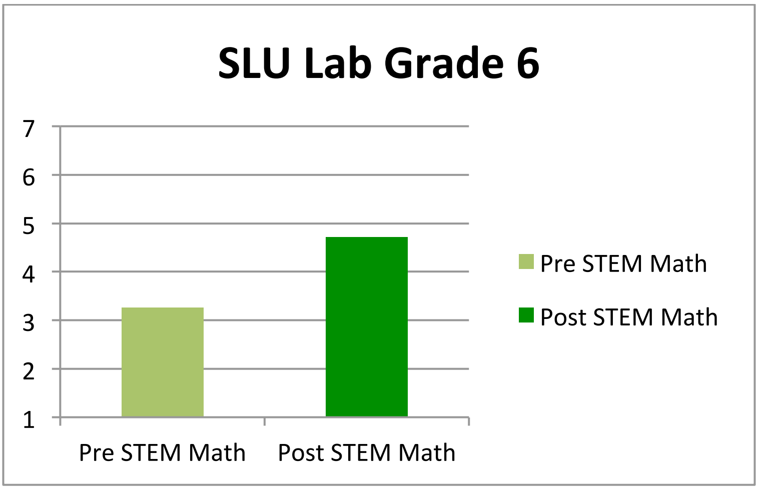

Figure 2. Pre-post gains in semantic perception of mathematics (6th grade students 2010-11).

Perceptions of and Aspirations for STEM Careers

Data gathered by the project's external evaluators over a two-year period indicates that MSOSW students emerge from project activities with increased aspirations for STEM-related careers. Five multiple-choice questions were selected by external evaluators and the advisory committee as relevant to this project. These were gleaned from the *National Center for Educational Statistics* and the *American Women in Engineering* item banks (www.nsf.gov/statistics). The largest pre-post school-year gains were related to students' understanding of what scientists do, in agreement that they can do many different jobs (12.1% increase), and that they can work on things that help the world (8.6% increase). The results of 2010-11 NELS item administration further indicates that students (n = 231) took greater part in, or became more aware of opportunities to engage in after school programs, computer clubs, and groups where they can build/design things.

The following 2010-11 trends were observed in students' responses to their future career aspirations:

- MSOSW students showed a 6% increase in desire to have a career with "work that makes me think."
- MSOSW students showed a 3.4% increase in wanting "work that allows me to make lots of money."
- MSOSW students showed a 3% increase in agreement with the statement that they will look for "work that allows me to use math, computer, engineering or science skills."

- MSOSW students showed a 4.8% increase in agreement with the statement that they will look for "work that allows me to tell other people what to do."
- There was a 2.6% increase for the project group in agreement with the statement that they will look for "work that allows me to help solve problems and create solutions."
- MSOSW students started at 85.7% and increased by 2.6% in agreement with the statement that they will seek "work that is fun to do."
- Starting at 70%, there was a 7% increase for MSOSW students in agreement with the statement that they will look for "work that allows me to have time with family."
- MSOSW students reported an 11.7% increase in agreement with the question that they will seek "work that allows me to help my community and/or society."
- There was a 6.9% increase in agreement with seeking "work that is satisfying to me."

Gender Differences

Gender-based differences in STEM perceptions were examined for science, technology, engineering, and mathematics content areas. A comparison of the gain scores in standard deviation units (effect size, pre to post) in STEM perceptions of female and male students is graphically illustrated in Figure 3.

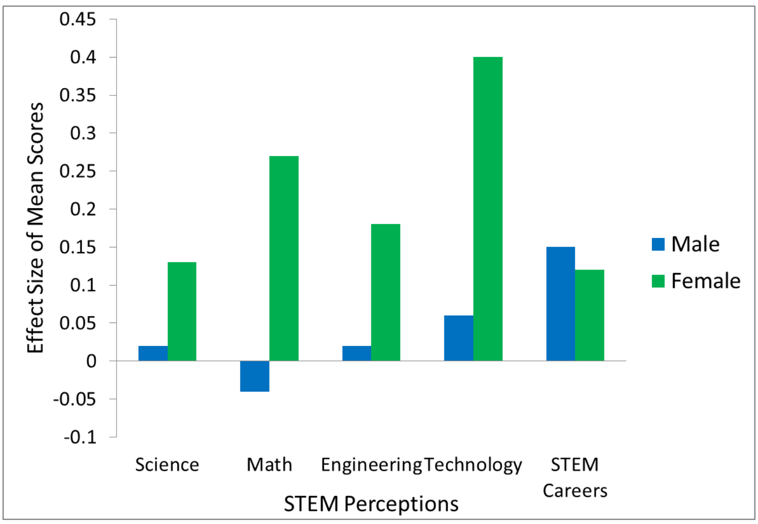

Figure 3. Gender differences in stem perceptions (Knezek et al., 2011)

These are based on detailed findings provided in Table 4. Female middle school students exhibited much greater pre-post gains than their male counterparts in perceptions of technology and mathematics. In addition females had considerably larger gains in perceptions of engineering and science. The female and male students displayed similar gains in their overall perceptions of choosing STEM as a career. Note that the comparatively large gains for females should be interpreted within the broader context of initially lower (pretest) dispositions for females in all areas except STEM career perceptions. The dispositions of females often rose extensively to become more comparable to those of males, over the course of the project school year.

Table 4. Gender Difference in STEM Perception Gains

		Male students				Female students			
		M	*n*	*SD*	*ES*	*M*	*n*	*SD*	*ES*
Science perceptions	Pre	5.32	77	1.31	0.02	5.07	68	1.44	0.13
	Post	5.35	77	1.52		5.25	68	1.69	
Mathematics perceptions	Pre	4.81	72	1.51	-0.04	4.50	71	1.56	0.27
	Post	4.75	72	1.63		4.91	71	1.77	
Engineering perceptions	Pre	4.89	70	1.52	0.02	4.66	67	1.40	0.18
	Post	4.93	70	1.82		4.91	67	1.83	
Technology perceptions	Pre	5.66	71	1.44	0.06	5.22	70	1.60	0.40
	Post	5.74	71	1.59		5.86	70	1.63	
STEM career perceptions	Pre	5.02	77	1.50	0.15	5.03	73	1.45	0.12
	Post	5.24	77	1.69		5.21	73	1.80	

DISCUSSION

Probable Impact of Socioeconomic Status

Several researchers have pointed out the academic disparities between students from low socioeconomic backgrounds and those from higher socioeconomic backgrounds on national-level standardized mathematics and science tests (Crosnoe, 2009; Woolley et al., 2010). Woolley et al. (2010) also pointed out that such achievement gaps are more of gaps in opportunities for learning and quality of services available to students in lower socioeconomic status. In a study by Boaler and Staples (2008), students in urban schools improved their mathematics achievement scores when teachers provided students with a wide range of learning opportunities rather than traditional lectures. Support from teachers and high expectations from peers, parents, and teachers also influenced students' mathematics achievement (Boaler & Staples, 2008). Although socioeconomic status was not a major research question addressed in the MSOSW project, the research team noted during site visits that the economic prosperity of the region of the U.S. in which participants resided (four U.S. states in the northeast and mid-south), as well as the neighborhood in which an individual classroom was located, appeared to impact the dispositions of students.

How does the impact of the MSOSW project activities differ for students of low versus high socioeconomic status? This specific research question was suggested by an MSOSW teacher in one of the Title I (free government lunch) schools participating in the project. This question cannot be properly addressed with the limited demographic data currently gathered for the middle school students participating in MSOSW. However, project researchers conjecture that students without access to the Internet at home generally come from families of lower socioeconomic status. An analysis of the 2010-11 matched pairs pre-post data (n = 255) revealed that approximately 10% (n = 23) of the students in this data set reported not having access to the Internet at home. An analysis of variance based on Internet access for STEM disposition and career interest gain revealed that students without access to the Internet at home became more positive from pre to post on all the major STEM indicators gathered, while for many with Internet access at home, the pre-post indicators declined. In the area of STEM perceptions of engineering and perceptions of STEM careers, gains were significantly ($p < .05$) greater for those without Internet access at home than for those with Internet access at home. These findings imply that MSOSW activities may be especially effective in promoting interest in STEM content and careers among disadvantaged students. Further research is needed in this area.

Probable Impact on Creative Tendencies

A subscale of the Computer Attitude Questionnaire (Christensen & Knezek, 2009; Knezek, Christensen, Miyashita, & Ropp, 2000) measuring creative tendencies was also used for this study. This instrument has been well-validated and employed in national and international comparisons in studies in the past (Collis et al., 1996; Morales, Knezek, Christensen, & Avila, 2000; Fluke, Knezek, & Christensen, 2001). The Creative Tendencies subscale contained 13 Likert-type items originating from the Netherlands and Japan and refined in the U.S. (Collis et al., 1996) with ratings ranging from strongly disagree (1) to strongly agree (5). Examples of items include: *I examine unusual things; I find new things to play with or to study without any help; When I think of a new thing, I apply what I have learned before;* and *I create many unique things*. The reliability estimate for this subscale was found to be very good (0.83) (DeVellis, 1991) for the students participating in the MSOSW project, and pre-post changes in this area were assessed.

How do the MSOSW project activities impact the students' assessment of their own creative tendencies? Findings from the Computer Attitude Questionnaire (see Table 5) showed that classrooms of students can become significantly more positive ($p < 0.05$) on the subscale Creative Tendencies over the course of a school year that includes MSOSW project activities.

Table 5. 6th Grade Creative Tendencies

Scale	*Group*	*Mean*	*SD*	*Paired t*	*Sig.*	*ES*
Creativity	Pretest	3.59	.41	-1.79	.042	.30
	Post-test	3.73	.51			

Note: N = 31

As graphically displayed in Figure 4, sixth grade students at an MSOSW school identified by project liaisons as employing teaching methods promoting creative uses of the monitoring equipment and data, increased on a 5-point Likert rating scale of: 1 = strongly disagree, 2 = agree, 3 = undecided, 4= agree and 5 = strongly agree, from pretest (M = 3.59, SD = 0.41) to post test time (M = 3.73, SD = 0.51).

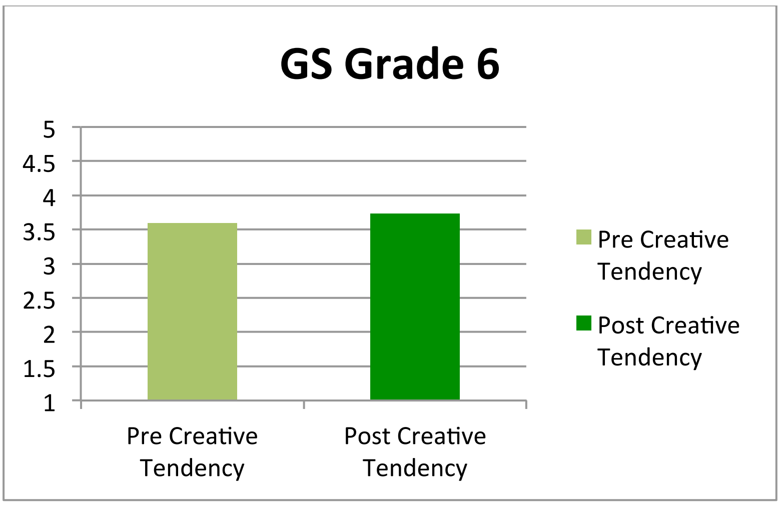

Figure 4. Pre-post gains in self-reported creative tendencies for 6th grade MSOSW students

Although the gain in creative tendencies was small, this increase in self-reported creative tendencies was unlikely by chance (t (30) = -1.79, $p <$ .05) and was of sufficient magnitude to be considered educationally meaningful (ES = 0.3) (Bialo & Sivin-Kachala, 1996). Overall, creative tendencies for females across project sites started lower than boys before MSOSW activities, and advanced toward the level of the boys by post-test time. The gain for girls was significant ($F(1, 231) = 4.17$; $p < .05$) and the effect size was approximately 0.3. Further research is needed in this area.

Findings in the National and International Context

Declining interest in science and the need to encourage STEM career aspirations and interests at an early age has been recorded by many researchers (Archer et al., 2010, Tai, Liu, Maltese, & Fan, 2006). The nature of work that students perform in the classroom influences their perceptions of mathematics and science and what students value as important to their learning (Haitham, 2002; Rukavina, Zuvic-Butorac, Ledic, Milotic, & Jurdana-Sepic, 2012). The findings of this study are consistent with those of Haitham (2002) in that student perceptions of mathematics and STEM content for females are positively impacted by MSOSW activities. Hands-on learning and inquiry-based problem solving helps students to become motivated independent learners–one of the main goals of education. Real world application of science and mathematics through active learning projects promotes interest in science and mathematics careers (Rukavina et al., 2012). Although young students might report that science is fun and interesting, this interest might not result in motivation to choose to study STEM areas and then pursue a career in STEM (Archer et al., 2010). The current study found positive indications that engaging students in hands-on STEM activities promotes interest in STEM careers.

Findings from the MSOSW study also indicate that a proper understanding of what a career in STEM entails needs to be embedded in the STEM curriculum. Similarly, in a study completed by Dyne and Fjermestad (2012), high school female students reported that they were not aware of computer science as a career path. Further investigation regarding what middle school students perceive as a STEM career is needed. A pilot study by the research team producing this paper (Periathiruvadi, Knezek, Tyler-Wood, & Christensen, 2012) has indicated that for the middle school students who participated in MSOSW, student dispositions towards science and mathematics had a greater influence on interests in pursuing a STEM career when compared to students' dispositions towards technology and engineering. Mills (2013) has confirmed a strong connection between middle school students' beliefs in their creative tendencies and the attractiveness of STEM as a career. These studies imply that STEM education in school should not stop at teaching only the why and how of science and mathematics concepts, but also relate it to real-world issues and career goals, as is recommended by Archer et al. (2010). Furthermore, rapidly changing technological advancements have resulted in a new set of career expectations especially in STEM fields (Roehrig, Moore, Wang, & Park, 2012). Real world problems are not isolated issues and often require multi-disciplinary problem solving approaches drawing on findings from STEM disciplines.

The overall findings from MSOSW are supportive of recommendations established by the European Commission (Rocard et al., 2007). In their review of instructional practices, the European Commission recognized that inquiry-based science education (IBSE) is effective with all kinds of students from the weakest to the most capable and that ISBE seems to be particularly effective at increasing girls' interest in science (Rocard et al., 2007). The major outcomes from MSOSW activities included large gains for middle school girls, with girls generally becoming more positive during the project year to become approximately equal with boys.

The European Commission (Rocard et al., 2007) supports the use of inquiry-based learning in the classroom as well as incorporating inquiry-based training into teacher education programs. The MSOSW project brought the project teachers together for several days each summer to test student activities and share successes and difficulties with other participating teachers. Support continued throughout the project year through online mentoring and problem resolution activities led by the project staff.

Finally, The European Commission (Rocard et al., 2007) indicates that inquiry-based science education (IBSE) can improve science learning at both primary and secondary levels by increasing students' interest. The overall findings from the MSOSW project strongly support this contention.

Recommendations for Classroom Improvement of STEM Interest

Implications of the collective findings of this study can be translated into several recommendations for teacher professional development and school practice.

- One recommendation is that schools / policymakers / districts / universities should provide additional training opportunities to increase the teaching skills necessary to implement an inquiry-based approach to STEM learning in the classroom. Additional training would allow teachers to incorporate inquiry- based learning modules into STEM teaching.
- As an additional recommendation, it is likely that community participation in critical STEM learning projects such as reducing the use of standby power would be an asset in encouraging interest in STEM careers. It has been noted that students often do not understand the relationship between what they are learning and a STEM career. Unless a family member works in a STEM field, most students do not know what an actual scientist or engineer does.
- A final recommendation is to provide a means to explore related STEM career opportunities as students acquire STEM knowledge in the classroom.

SUMMARY AND CONCLUSIONS

Four research questions were introduced at the beginning of this paper. Major results related to each of these were:

1. Students taking part in the MSOSW project activities showed a significant and meaningful gain in their STEM content knowledge tested using the National Geographic Vampire Power test. Both boys and girls improved in their STEM content knowledge.
2. Findings on the gain in STEM perceptions after participating in MSOSW activities confirmed that more positive dispositions are emerging in selected areas. Students from one school came to see mathematics as more appealing, more exciting, and less boring.
3. MSOSW students emerge from project activities with increased aspirations for STEM-related careers. The largest pre-post school-year gains were related to two survey questions on students' understanding of what scientists do, namely agreement that scientists can do many different jobs and that scientists can work on things that help the world.
4. A comparison of the gain scores in STEM perceptions for female and male students showed that female students reported greater increases in their perceptions of science, engineering, mathematics and technology. Female students reported greater gains in their perceptions of technology and mathematics followed by engineering and science perceptions.

Other findings have also emerged from this study. To determine the influence of socio-economic status, comparison of gains in STEM dispositions and career interests were made between students who had access to Internet and those who did not. Students without access to the Internet at home became more positive from pre to post on all the major STEM indicators gathered. These findings imply that MSOSW activities may be especially effective in promoting interest in STEM content and careers among disadvantaged students.

Another area deemed especially worthy of further study is creative tendencies. Student participants in MSOSW, especially selected sixth graders, reported more positive self-assessment of their own creative tendencies. Although the gain in creative tendencies was relatively small, this increase in self-reported creative tendencies was unlikely by chance and was of sufficient magnitude to be considered educationally meaningful. Further research is needed.

Overall, we conclude that middle school students definitely gain STEM content knowledge during MSOSW activities. More positive dispositions toward science, technology, engineering and mathematics are emerging in selected areas, with multiple measures providing evidence of increased interest in STEM careers. Increased students' perceptions of their own creative tendencies appear to be an additional project outcome. Gains for females are especially large, as are those for students (which we assume to be from disadvantaged families) without access to the Internet at home. Further research is needed to confirm these findings on a broader scale outside the four U.S. states and approximately 600 middle school students involved in the project across these states.

ACKNOWLEDGEMENT

This research was supported by U.S. National Science Foundation Innovative Technologies Grant ITEST #0833706. The authors also wish to acknowledge the contributions of external evaluators Penny Nolte and Doug Harris to the findings presented in this paper.

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APPENDIX 1

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