Final Performance Report

Center for STEM Education in the National Institute of Science, Space, and Security Centers (NISSSC)

Title: (Congressional Add) Partnership in Innovative Preparation for Educators and Students (PIPES)
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ABSTRACT

The Center for Science, Technology, Engineering, and Mathematics Education (CSTEME) was one of four sponsored centers through the National Institute of Science, Space, and Security Centers located on the University of Colorado, Colorado Springs (UCCS) campus and initially funded by the U.S. Air Force Office of Scientific Research (AFOSR). Through its **Partnership in Innovative Preparation for Educators and Students** (PIPES) program, CSTEME responded to the lagging performance and retention of students in science and math through innovative and supportive partnerships with parents, educators, and professionals. Leveraging on-campus faculty as well as the technology and military industries that are so prevalent in the Pikes Peak area, CSTEME aspired to attract and encourage a new generation of creative, artistic, and innovative students to solve our future problems related to science, technology, engineering, and mathematics (STEM). Underlying all PIPES activity was a solid evaluation framework that measured student interest and retention in STEM subjects through longitudinal tracking of students from 6th through 12th grade and assessing teachers who completed PIPES professional development programs over 4 years. PIPES researchers collected and analyzed both qualitative and quantitative data from students, teachers, and parents related to PIPES program effectiveness in stimulating interest in STEM subjects and long-term attraction and retention in STEM careers.

INTRODUCTION

The Center for Science, Technology, Engineering, and Mathematics Education (CSTEME) was one of four sponsored centers through the National Institute of Science, Space, and Security Centers located on the University of Colorado, Colorado Springs (UCCS) campus and originally funded by the U.S. Air Force Office of Scientific Research (AFOSR) (FA9550-06-1-0477). Through its **Partnership in Innovative Preparation for Educators and Students (PIPES)** program subsequently funded through AFOSR (FA9550-07-1-0188), CSTEME responded to the lagging performance and retention of middle and high school students in science and math through innovative and supportive partnerships with parents, educators, and professionals. Leveraging on-campus faculty as well as the technology and military industries that are so prevalent in the Pikes Peak area, CSTEME aspired to attract and encourage a new generation of creative, artistic, and innovative students to solve our future problems related to science, technology, engineering, and mathematics (STEM). The funding received from AFOSR for this award has supported the initial PIPES study for the last 4.5 years and the research continues through a current follow-on award (FA9550-09-1-0713) through 29 September 2013.

CSTEME offered an array of programs for students from regional middle and high schools that provided participants opportunities to explore careers in STEM fields. The program targeted over 1,000 students and 100 teachers, most of whom were from underserved school districts. These students and teachers were introduced to innovative courses and hands-on workshops that challenged their minds in a creative and energetic atmosphere.

Underlying all PIPES activity was a solid evaluation framework that measured student interest and retention in STEM subjects through longitudinal tracking of students from 6th through 12th grade and assessing teachers who completed PIPES professional development programs over 4 years. PIPES researchers collected and analyzed both qualitative and quantitative data from students, teachers, and parents related to PIPES program effectiveness in stimulating interest in STEM subjects and long-term attraction and retention in STEM careers. Changes in student attitudes, career interest, intention, retention, and academic achievement in STEM subjects were evaluated. The results of this research provided crucial guidance in developing STEM education programs that increased student engagement, performance, and retention in STEM subjects from 6th through 12th grades. Longitudinal research on this scale is rare and necessary to adequately address the STEM pipeline shortage facing our nation. In the future, these outcomes will inform other ongoing STEM education research projects and will provide guidance to educational and policy leaders.

PIPES research provided tangible results to the Air Force by directly addressing the concern about maintaining a workforce with the requisite STEM skills needed to support the Air Force's mission needs (Science, C. o. E. o. t. U. A. F. s., Engineering, 2010). Furthermore, PIPES addressed the STEM professional shortage by researching the most effective ways of developing STEM cognizant students who pursue a STEM degree after graduation.

STUDENT MODEL

The PIPES student research model (see Figure 1) was undertaken after a thorough and rigorous review of the literature. The model emerged from best practice recommendations from nationally recognized STEM education organizations such as the National Science Foundation, the National Science Teachers Association, Project 2061, the American Association for the Advancement of Science (AAAS), the National Academies, and the National Research Council. Based on the prior work of these organizations the PIPES program model was formulated that encompassed inquiry learning, longitudinal student engagement, and industry engagement. PIPES student programs were built around the 5E model of inquiry (Flick, 1995) shown to engage students at deep levels of questioning, and participation (Banilower, Cohen, Pasley, & Weiss, 2008). In addition, PIPES student programs utilized problem based (Lampert, 2001), authentic learning (Albanese,M. A., and Mitchell, 1993) constructivist pedagogies (Lombardi & Oblinger, 2007) requiring collaboration with peers within a distinct learning context that students can easily relate to (Stanley, E., and Waterman, 2005). The longitudinal nature of student and parent support was found to substantially increase student retention and interest in STEM content (George, 2006).

PIPES RESEARCH MODEL

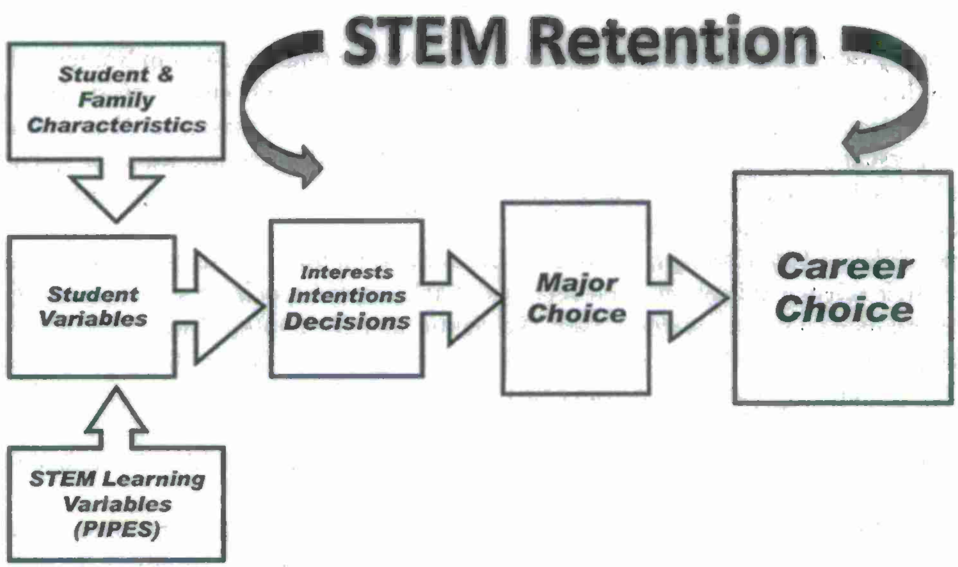


Figure 1

This study utilized two constructs as the independent variables. These constructs included

Student and Family Characteristics – demographics (i.e., age/grade, gender, race, ethnicity, household income), parents' education / occupation, and parents' expectations for college and;

STEM Learning Variables – PIPES workshops and summer camps intensity, measured in hours of participation in PIPES, duration, and breadth-variety of programs (STEM dose).

The constructs used as the dependent variables were

Student Variables (variables affecting the student's interest and intentions toward STEM) – motivation for STEM career, science & math self-concept and self-efficacy, attitudes toward science and career in science, science confidence & knowledge, social niche, science and math achievement, parent attitudes toward STEM, family encouragement, peer influence, and teacher encouragement.

The research questions explored by the PIPES student model were whether there were statistically significant relationships between longitudinal STEM dose and the following outcome measures:

1. ***Self Efficacy (SE)***: Drawing from Bandura (1977) who hypothesized that beliefs about self-efficacy were formulated from individual's perceptions from four sources: mastery experience, vicarious experiences, social persuasions, and physiological states we use adapted versions of the Sources of Mathematics Self-Efficacy Scale (SMES) originally developed by Lent et al. (2001) and later adopted for use with science by Britner & Pajares (2006).
2. ***Sources of Math Self-Efficacy*** were evaluated by adopting the 24-item Sources of Middle School Mathematics Self-Efficacy Scale (Usher & Pajares, 2009) for use in this study. This scale consisted of 4 subscales listed here with corresponding Cronbach's alpha coefficients reported by Usher & Pajares: mastery experience (.88); vicarious experiences (.84); social persuasions (.88); and physiological states (.87). Construct validity was also explored by Usher & Pajares as they found that the items both individually and collectively were correlated with four self-efficacy measures (i.e., math grade SE, math skills SE, math courses SE, & self-regulatory SE), as well as, self-concept and semester GPA. Correlations between the sources and SE were all statistically significant ($p < .001$) with the highest correlation found between mastery experience and SE (.77).
3. ***Sources of Science Self-Efficacy*** were assessed by adopting the 24-item Sources of Middle School Mathematics Self-Efficacy Scale (Usher & Pajares, 2009) for science. Britner & Pajares (2006) reported Cronbach's alpha reliability indexes as .90 for mastery, .80 for vicarious, .88 for social persuasions, and .91 for physiological state when adopting the scale for science for use with high school students from the original scale used to measure this construct in the field of mathematics in college-aged students.
4. ***Math / Science Self-Concept***, defined by Britner and Pajares (2006) as "students' perception about their science ability and their feelings of self-worth associated with this ability," were evaluated using a 6-item science scale, Academic Self Description Questionnaire (ASDQ-1) developed by Marsh (1990). Alpha coefficients ranged from .88 to .94 on the 13 subscales in the ASDQ-1, including the science scale; while, Britner & Pajares (2001) reported a Cronbach's alpha coefficient of .82, in 2006, Britner an Pajares reported a coefficient of .89.
5. ***Attitudes toward Science and Career in Science*** were measured with a 16-item survey designed for use in the current study.
6. ***Family Encouragement*** was measured with a 4-item scale developed by Stake & Mares (2001) which looked at student perception of encouragement from family members for science pursuits. Using a 7-point scale 1 (not at all true) to 7 (very true), internal reliability was reportedly .85. We have elected to use a 6-point scale instead.
7. ***Peer Encouragement*** was assessed with a 7-item scale adapted from the Friends' Attitudes Toward Science subscale developed by Simpson and Troost (Owen et al., 2008). Through factor analysis and cross-validation methods with a large sample of middle school students, Simpson and Troost found the subscale distinctly differentiated from 14 other school, home, and self variables pertinent to science evidencing adequate internal reliability (.71). Stake and Mares adopted the scale using 5-items for use with high school girls and found internal reliability to be .70.
8. ***Teacher Encouragement***, also adopted from Simpson and Troost was measured with a 6-item scale adapted from the Science Teacher subscale using the same procedures described for the Friends subscale. The original scale had low internal reliability (.44); but, Stake and Mares reported adequate internal reliability (.79).
9. ***Motivation for Science Career*** was assessed using a 4-item scale developed by Stake and Mares (2001) to evaluate science enrichment programs for gifted high school students. They used a seven point scale ranging from "not at all true" to "very true" and reported an internal reliability of .93 at pretest and .95 at posttest and follow-up. We used a six point scale "not at all true" to "definitely true" for the present study.
10. ***Science / Math Grade SE*** was assessed using 3-items asking students to provide a rating of their level of confidence in achieving an A, B, or C in their science/math class. Alpha coefficients

ranging from .69 to .85 have been reported by past researchers when academic SE has been measured similarly.

11. ***Math / Science Aptitude***, defined by scores on standardized tests (i.e., CSAP, ACT) were obtained from student transcripts.
12. ***Math / Science Achievement*** was defined as students' grade in science/math class at the end of each grading period.
13. ***Science and Math Career SE*** was measured by asking students how confident they are that they will choose a career in each field, using a 6-point scale ranging from "not at all confident" to "completely confident."
14. ***Course Intentions*** were evaluated by asking students to identify STEM courses they intended to take in the future from a list provided. Other researchers measured this construct similarly (Lent et al., 2001). In 1993, Lent et al., obtained an alpha coefficient of .77 and discovered that it correlated significantly with math self-efficacy, interests, and math ability. Lent et al. reported an alpha coefficient of .76 for a similar course intention measure.
15. ***STEM Career Interests*** were assessed by asking students to list 3 jobs they might like to have when they grow up. Students were also asked to report how interested they were in 19 different STEM careers using a 6-point scale ranging from "not at all interested" to extremely interested." This method was consistent with social cognitive research on math outcomes (i.e., Lent et al., 2001). Lent et al. reported an alpha coefficient value for a similar measure as .84.
16. ***Student perceptions of program impact on their motivation for science*** was assessed using a 6-item scale developed by Stake and Mares (2001). Internal reliability was .89 at post testing and .93 at follow-up.
17. ***Student perception of program impact on their science confidence*** was assessed using a 6-item scale developed by Stake and Mares (2001). Internal reliability was .92 at post testing and .93 at follow-up.
18. ***Student perception of the extent to which the program increased their science knowledge*** was assessed using a 6-item scale developed by Stake and Mares (2001). Internal reliability at posttesting was .79.
19. ***Student perception of the extent to which the program helped them to develop a network of friendships with other science students (a new social niche)*** was assessed using a 5-item scale developed by Stake and Mares (2001). Internal consistency at post testing was .85 and at follow-up it was .83.

The basis of the PIPES program was to provide a developmentally appropriate longitudinal sequence of hands-on STEM workshops for academically motivated students from predominantly underserved school districts. PIPES students engaged in a maximum of 424 possible hours of peer collaboration, lab and field work, engineering design, and innovative problem solving alongside graduate level facilitators, school district secondary master teachers, university faculty, and industry professionals. Starting in 6th grade, PIPES students were exposed to a wide array of STEM topics (see Appendix 2). As they transitioned to high school, students were engaged in deeper learning through multiple, in-depth experiences in a STEM related topic of their choice. PIPES programs included:

- ***Mind Quest:*** A series of middle and high school workshops held four times per academic year covering a variety of STEM topics (i.e. computer science, engineering, food science, and biotechnology).
- ***STEM in Real Life:*** A two-day summer camp for middle school students designed to allow each participant to experience the wide breadth of STEM subjects present in society today.
- ***FLITE (First in Leadership, Innovation, Technology, and Engineering):*** A week-long summer camp for high school students to engage in research, engineering, and innovation by working with industry mentors and university graduate students.

- *JUMPSTART:* A week-long summer camp for high school students which offers students the opportunity to apply their STEM knowledge to real-world scenarios. Each scenario is built around a central story in which students answered a critical question through experimentation and data analysis.
- *Math Bridge:* The capstone experience for PIPES high school students which offered students the opportunity to assess their math skills and remediate any deficiencies. The goal of the course was to create a pathway for students to enter Calculus I as an undergraduate freshman with no need for remediation.

EDUCATOR MODEL

The second tier of the PIPES program emphasized science and math teacher professional development. Long term STEM retention is heavily dependent on qualified and enthusiastic teachers utilizing high engagement strategies to retain student interest in STEM subjects (National Research Council, 2005). To this end, PIPES developed two teacher professional development models for secondary science and math teachers. The model was built around the notion that ongoing, collaborative development was the key to reform in science and math classrooms (Lieberman, 1996) which generated meaningful discussion among peers (Carey, N., & Frechtling, 1997) leading toward the creation of teacher-leaders (Darling-Hammond, L., & McLaughlin, 1995). Science professional development was also built around the 5E model to encourage deeper engagement and student understanding (Bybee, 1997) (Eisenkraft, 2003), and inquiry skills in both teachers and their students (Davis, E. A. & Krajcik, 2005). In addition, meaningful formative assessment strategies were extensively covered and modeled (Driver, R., Guesne, E., Tiberghien, 1985).

The independent variable used in this study was whether a teacher had completed the PIPES professional development program. The dependent variables examined were teacher self-efficacy, confidence, and instructional practices. These constructs were measured using two different instruments for science and math. The science teacher constructs were assessed by administering the Teaching Science as Inquiry Instrument (TSI) (L. D. Smolleck, Zembal-Saul, & Yoder, 2006) and the Local Systemic Change (LSC) mathematics teacher questionnaire developed by Horizon Research, Inc.(CPRE Policy Brief, 2006).

The TSI was validated by Smolleck, Sembal-Saul, and Yoder (2006); and L. A. Smolleck & Yoder (2008) to measure teacher self-efficacy in reformed settings. Intended for pre-service and beginning teachers, the TSI investigates the connection between teacher beliefs and the teaching of science as inquiry. According to Heath, Lakshmanan, Perlmutter, & Davis (2010) the instrument "incorporates the five features that define teaching and learning science as inquiry across all grade levels and that the learner: (1) engages in scientifically orient questions, (2) gives priority to evidence in responding to questions, (3) formulates explanations from evidence, (4) connects explanations to scientific knowledge, and (5) communicates and justifies explanations." The TSI had 69 items that demonstrated acceptable validity and reliability. Overall alpha coefficient reliability scores in relation to self-efficacy reported by Smolleck & Yoder (2008) were .94 at pre-test and .89 at post-test. In relation to outcome expectancy, the pre-test alpha coefficient as .90 and at post-test, .90.

The LSC underwent test-retest analysis by Germuth, Banilower, & Shimkus (2003). The study provided correlation coefficients for each of the eight composites greater than 0.60. These results, added to those of past studies, established the questionnaire's validity and the internal reliability of the composites. Based on these findings, the LSC teacher questionnaire was found to be a valid and reliable measure of teachers' attitudes, preparedness, and classroom practices.

The basis of the PIPES teacher professional development model was the development of professional learning communities (PLC's) in which teachers could learn from the instructors and their peers through ongoing professional development which included

- *PIPES Science Educator Academy:* This professional development opportunity provided secondary science teachers with high quality, inquiry-based science content and instructional strategies. These courses were taught by UCCS faculty and veteran master science teachers.
- *Pikes Peak Math Teachers' Circle:* This professional development academy provided secondary math teachers with the opportunity to engage together as a cohort for one academic year in high level mathematical reasoning, problem solving, and applied skill development.

DESCRIPTION OF PIPES STUDENTS AND EDUCATORS

- ***Student Numbers and Demographics:*** The number of participating students started at 45 in 2008 and grew to 1,171 PIPES-enrolled students in 2011 (see Figure 2).

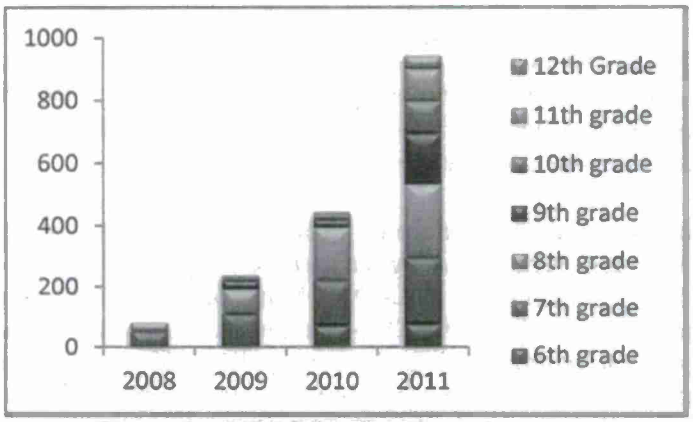


Figure 2 – PIPES Student Growth

The gender distribution of PIPES student populations was 60% female and 40% male. Ethnic origins were 29% non-white (12% African American), 28% Hispanic, and 57% Caucasian (see Figures 3 and 4).

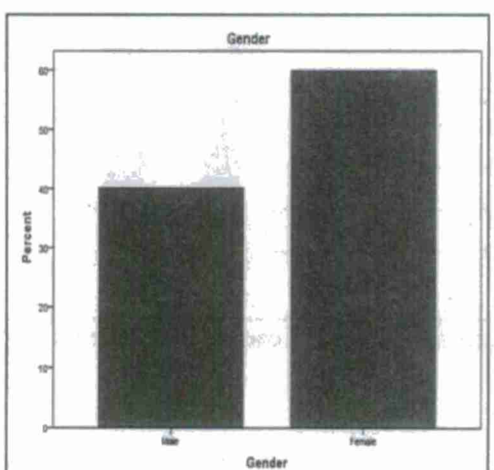


Figure 3 – Percentages by Gifted Status of PIPES Enrolled Students (n = 1,171)

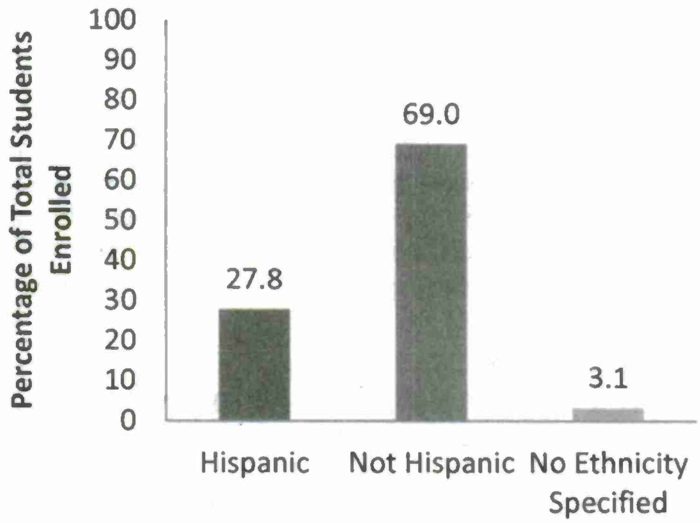


Figure 4 – Percentages by Ethnicity of PIPES Enrolled Students (n = 1,171)

More than half of the students came from underserved, low socioeconomic status school districts serving the Colorado Springs region. A significant number of PIPES students (38%) were served by resources for the gifted and talented in their schools. This study used a longitudinal model to track students from one grade to the next.

- ***Teacher Numbers and Demographics:*** The number of participating teachers began in 2008 with 15 science teachers, each impacting an average of 150 students per year, which exceeded 2,000 students annually. In 2009, the Pikes Peak Math Teacher's Circle was added with a cohort size of 38 (see Figure 5). By 2011, PIPES programs had instructed 80 math teachers and 64 science teachers, for a total student impact in excess of 20,000 students annually. Thirty-two percent taught in schools in which the majority of students qualified for free and reduced lunch services. Fifty-five percent taught in schools with 30% or above minority student populations.

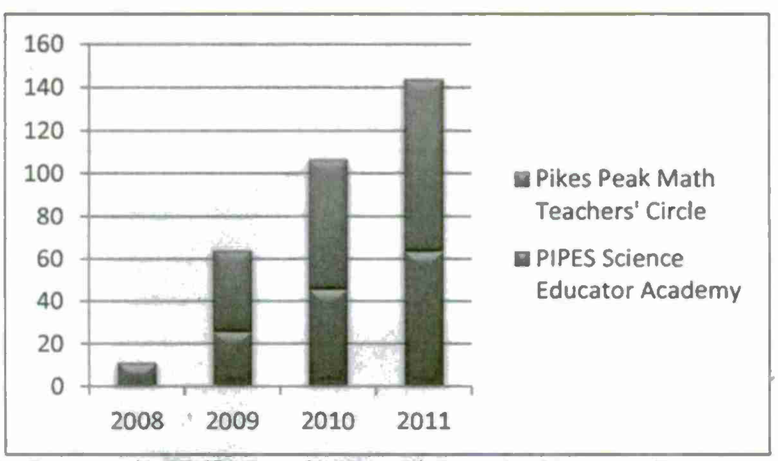
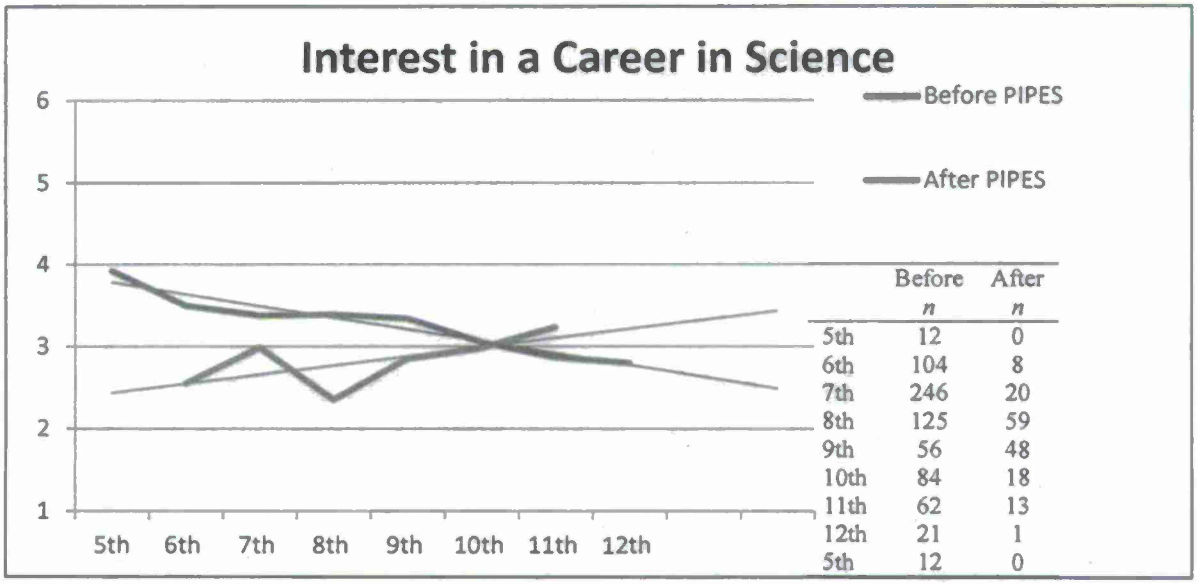


Figure 5 - Increase in PIPES Teacher Enrollments by Year and Program (n = 144)

RESULTS

Preliminary Student Results: The PIPES project, with AFOSR support, produced significant results as early analyses showed increased STEM interest and future career intent among students. These data were produced from student surveys given before PIPES involvement (pre-survey) and after one year of PIPES involvement (post-survey). Qualitatively, comments from students, parents, and teachers showed a high level of enthusiasm for PIPES programs (see participant comments, Appendix 3). Student perception, motivation and confidence were linked to the desire to pursue science further in college. Post-program survey results revealed that PIPES programs had a positive influence on students' internal motivation to study science, student confidence in their ability to do science, their general science knowledge, and achievement (see Figures 6-9). This suggests that if continued, the PIPES model of student outreach may be an effective program in attenuating the current downward trend of students' interest in careers in science as they transition into high school, thereby improving the likelihood that students will choose a STEM related career.



	Before *n*	After *n*
5th	12	0
6th	104	8
7th	246	20
8th	125	59
9th	56	48
10th	84	18
11th	62	13
12th	21	1
5th	12	0

Figure 6 – Means of Student Interest in Science Careers (1 = Definitely false, 6 = Definitely true) Before PIPES and After PIPES by Grade with Linear Projections

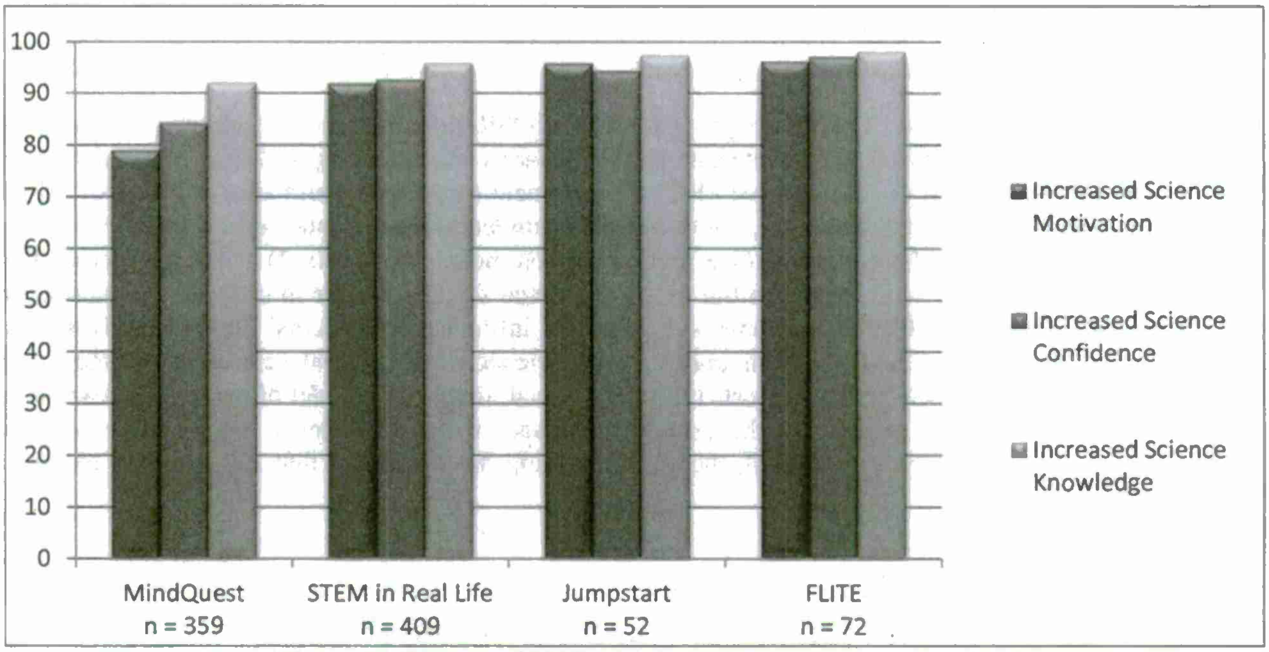


Figure 7 - Percent of PIPES Students Reporting Increases in Science Motivation, Confidence, & Knowledge after Participating in STEM Programs

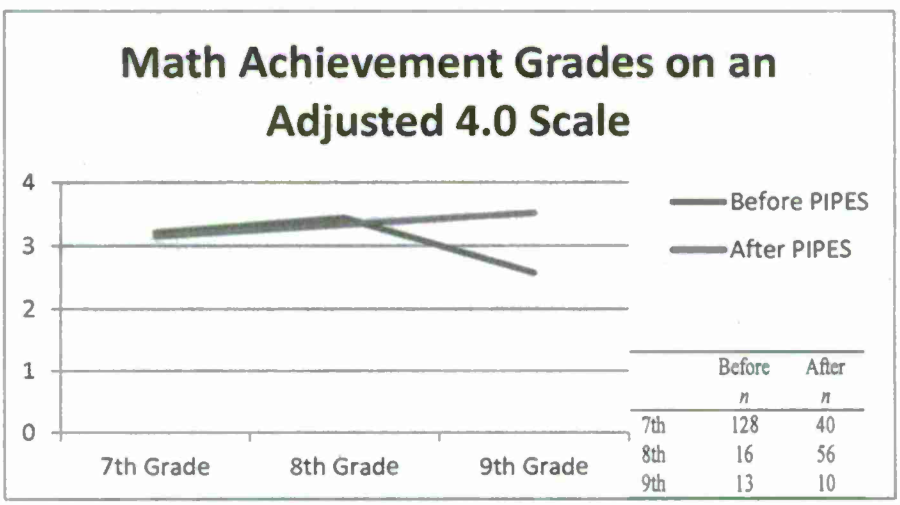
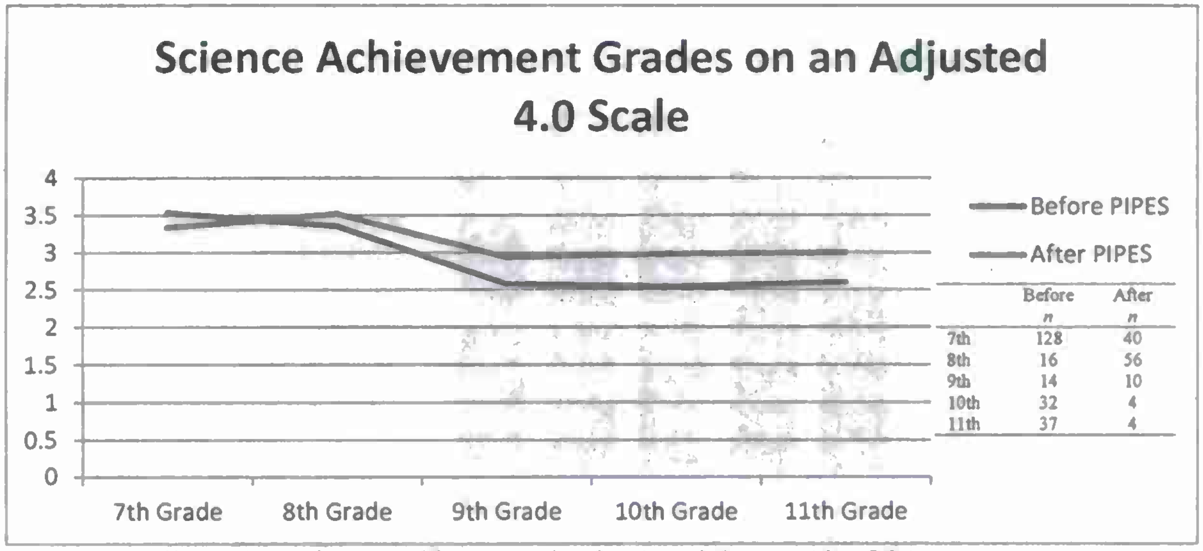


Figure 8 - Math Achievement by Grade as Measured by GPA



	Before *n*	After *n*
7th	128	40
8th	16	56
9th	14	10
10th	32	4
11th	37	4

Figure 9 – Science Achievement by Grade as Measured by GPA

Preliminary Teacher Results: Since the first PIPES professional development programs for STEM educators in 2008, early data indicated that the PIPES model was also improving science and math teachers' confidence. Increases in teacher confidence (self-efficacy) and outcome expectancy were linked to increased student understanding of course content (Liu, 2010). This increased understanding was found to increase student self-efficacy (Britner & Pajares, 2005) which significantly increased the likelihood that the student chose a STEM career (George, 2006). Among science teachers served, significant increases were observed in the science teachers' confidence to teach science content using inquiry-based methods (self-efficacy) after being in the program for one year. Additionally, these increases were accompanied by an increase in their confidence that the implementation of their newly developed teaching skills will increase student achievement outcomes (see Figure 10). Among math teachers served, significant increases were observed in their confidence to provide guidance to their students and to develop and lead an investigative culture in their classrooms (see Figure 11). This suggests that if continued, the PIPES model of teacher professional development may result in hundreds of science and math teachers potentially influencing thousands of students to pursue a STEM major and career field.

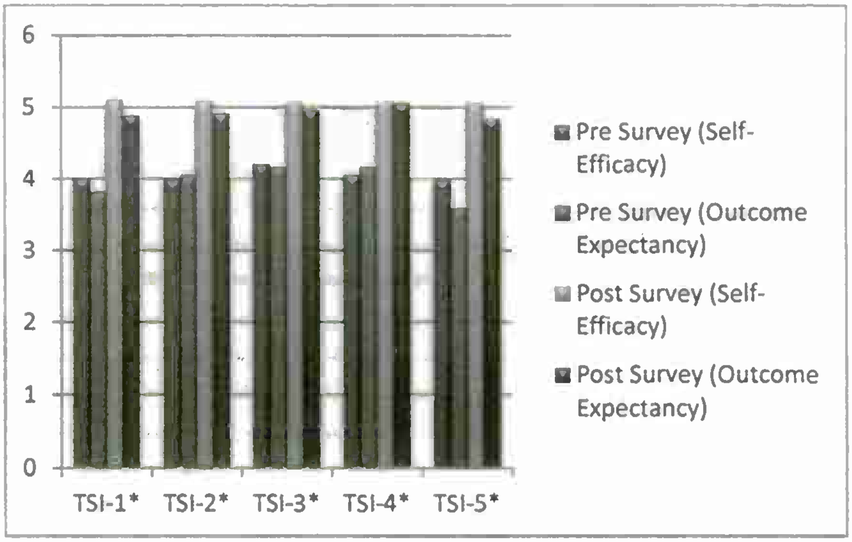


Figure 10 – Means of PIPES Science Teachers Increased Confidence Measures
*Denotes Statistically Significant Differences (n = 64)

(TSI-1) Learner engages in scientifically oriented questions
(TSI-2) Learner gives priority to evidence in responding to questions
(TSI-3) Learner formulates explanations from evidence
(TSI-4) Learner connects explanations to scientific knowledge
(TSI-5) Learner communicates and justifies explanations

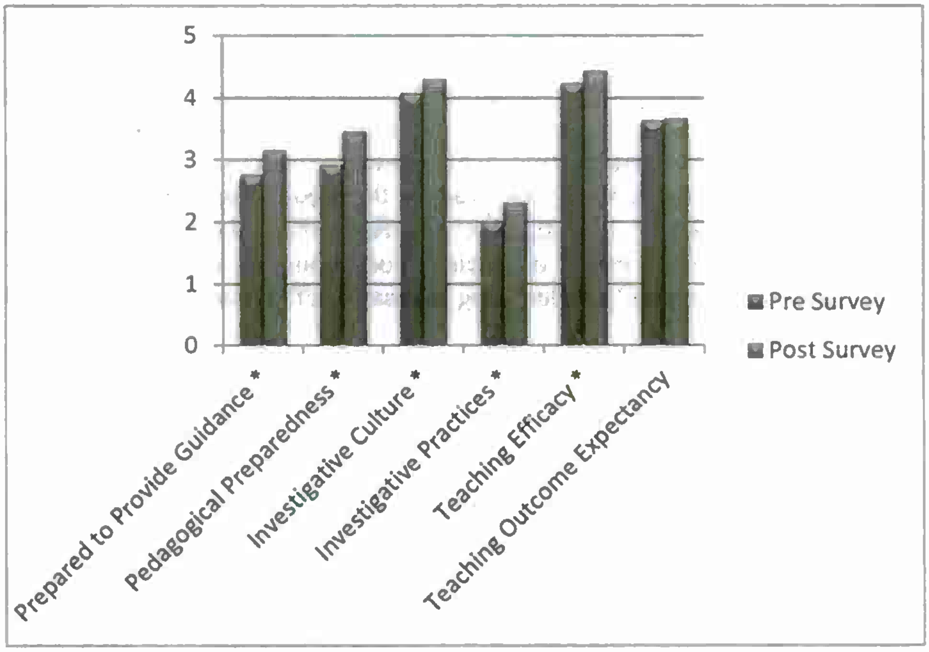


Figure 11 - Means of PIPES Math Teachers Increased Confidence Measures
*Denotes Statistically Significant Differences (n = 80)

Preliminary Replication Results: In June, 2011, the STEM In Real Life middle school camp was replicated at Otero Junior College, a small community college located in the underserved southeastern corner of Colorado. Sixty-three students were served and preliminary research results showed very similar patterns to the UCCS program, suggesting that the program components are portable to other locations around the country. Based on these preliminary results, replication sites are being added in Pennsylvania, Connecticut, and Colorado for PIPES programs.

The quality of the PIPES program has generated research partnerships with the University of Wyoming, Cornell, and Cal Tech. The work begun in Colorado Springs is paying dividends nationally. Projecting from current PIPES student and educator enrollment patterns and anticipated replication opportunities, in 4 years over 100,000 students will have been impacted by PIPES programs, with the potential to reach over 500,000 students in just 10 years.

CONCLUSION

The initial funding from AFOSR to establish the PIPES program helped to develop a research based program for STEM outreach, training, and research for students and teachers. The time, effort, and money that AFOSR has provided have been instrumental in producing tangible, measurable results, but the work is not yet finished. The PIPES program has begun to establish a national presence through ongoing efforts to replicate the program at sites nationwide. With follow-on funding, the PIPES research model will be able to answer the ultimately crucial question in which the Air Force and others are most interested: *What critical components are needed to produce the greatest return on investment in regard to attracting and retaining a STEM educated [military] workforce?*

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APPENDIX 1 – PIPES WORKSHOPS

- **Indoor Flyers** – Are you interested in airplanes and flight? Join this workshop that explores the mechanics of flight by building your own ultra-light rubber band powered airplane that really flies.
- **Solar Car Sprint** – How do solar panels work? Learn how by constructing a working solar powered model car as you examine photovoltaic cells, gear ratios, and electronics.
- **Bridge Building** – Are you a bridge builder? Come find out by constructing wood bridges to see how much weight your design can hold.
- **Green Energy** – You are hearing about "Green Energy" but what is it? Sign up for this workshop to find out! You will construct a working wind generator to find out which turbine generates the most electricity.
- **Computer Game Design** – Do you like computers and problem solving? Join this fun workshop to use Robocode software to develop a robot battle tank. Battle against other tank creations in a contest of strategy and problem solving.
- **LEGO Robots** – Do you like LEGOs? Are you interested in robots? Join this workshop where you can combine your interests to build and program a LEGO Mindstorm robot to perform certain tasks on a playing field.
- **Advanced LEGO Robots** – Do you have some experience with LEGO Mindstorm robots and want to go bigger with your creations? Join this workshop to build and program an advanced robot that will accomplish a greater number of amazing tasks using additional sensors and commands. Requires some previous NXT experience.
- **Drawdio** – How do music, electronics, and creativity relate? Make your own Drawdio pencil to find out. You will use high tech tools to construct a circuit that turns an ordinary pencil into a cool electronic musical instrument. Make a pencil that lets you draw music.
- **Animatronics** – What happens when high tech electronics are combined with your artistic creativity? Join this workshop to make high tech "creatures" that respond to things around them.
- **Rockets** – What does it take to launch a rocket successfully? Join this workshop to build and launch a basic Estes rocket.
- **Advanced Rockets** – Have you launched rockets using small A engines? Try your hand at designing and flying a bigger design with bigger engines. Requires some previous rocketry experience.
- **Card Game Design** – Do you love games? Ever thought you might be able to design your own? Join this workshop to explore the process of inventing a card game.
- **Cyber Security** – You hear about "cyber security," but what is it? Join this workshop to use high tech wireless networks and cell phones to solve a cyber-bullying mystery . Learn ways to stay safe online.
- **Kitchen Chemistry** – Science and food, what could be better? Join this workshop to explore the role that chemistry has in developing artificial flavors.
- **Mousetrap Vehicles** – Do you like to tinker and experiment? Join this workshop and use common household materials to construct a race car powered by the kinetic energy stored in a mouse trap.

- **GPS and Geocaching** – You hear about "GPS," but what is it and how is it used? Join this workshop to learn how to use GPS technology and mathematics to find hidden treasure on a geocaching course.
- **Battery Buggies** – Calling all gear heads! Join this workshop to use principles of mechanical engineering and electricity to construct and race a car of your own design.
- **Wildlife Biology** – Do you love being outside and seeing wildlife? Join this workshop to explore the roles that wild animals play in ecosystems, and engage in work that a real wildlife biologist and forester will engage in.
- **Veterinary Medicine** – Do you love animals? Does a career working with them sound interesting? Join us in veterinary medicine to find out how animals are treated and diagnosed.
- **Crime Scene Investigation** – Do you love a mystery? Join this workshop to piece together a crime from forensic clues gathered at a mock crime scene.
- **Astronomy** – What is the closest galaxy to ours? Why do galaxies hum? Join this workshop to learn about stars, planets, and our solar system using high tech tools of astronomy.
- **Physics of Filmmaking** – Ever want to break through glass without getting hurt? Turn yourself into a superhero by making a short movie trailer that uses digital special effects. Explore the physics of how special effects work, and shoot your own footage.
- **Sports Medicine** – How do athletes train, and how does a physical trainer know what exercises an athlete should do to be at the top of his or her game? Examine how the human body responds to certain activities and how these responses are measured.
- **Animal Behavior** – How do animals respond to their environments? If you are interested in how animals are trained and behave, join us for this interesting workshop.
- **Biotechnology** – What is DNA and how is it used? Join this workshop to extract and see your own DNA as well as to perform other experiments related to biotechnology.
- **Building Trades/Civil Engineering** – Students interact with the science and math behind buildings; their design, and construction.
- **Health Sciences** – Thinking about medical school? Join us in this workshop to discuss how doctors diagnose and treat diseases.
- **Rocket Chemistry** – Students interact with basic chemical reactions including how glow sticks work, how cold packs work, and other common chemical reactions.
- **Audio Engineering** – Are you an aspiring musician? Join us in this workshop to examine the physics of sound in musical instruments, and apply your knowledge to your own digital recording.
- **Emergency Response** – Students will examine the science and technology of how first responders, like police and fire departments, respond to emergencies.
- **Math Powered Art** – Students will create their own unique art using fractals, Fibonacci sequences, and Pascal's triangle.
- **Cryptography** – Do secret codes interest you? How does computer encryption work? Join this workshop to learn about the math, science, and linguistics behind creating and breaking codes and ciphers.
- **Liquid Crystals** – You see LCD screens everywhere, but how do they really work? Join this workshop to make your own liquid crystal pixel, and understand how all of those pixels form a high definition picture on an LCD screen.

- **Chemistry of Smell** – How do we smell things? What is happening in our brains when we smell something? Join this workshop to understand the chemistry and biology of smell, and become an olfactory engineer by designing your own scents.
- **Military Science** – Do you like strategy games? Apply your strategic thinking skills in this workshop to outwit your opponents in a friendly battle of logistics and problem solving.
- **Snap Circuits** – Do you like electronic gadgets and wonder what all those little parts in a circuit actually do? Join this workshop to find out by making your own circuits, and find out what all those little parts actually do!

APPENDIX 2 – PARTICIPANT COMMENTS

Student responses to: ***"My favorite part of this camp or workshop was:"***

- "Trying to use logical reasoning by trying to solve the crime"
- "Being able to visit the campus and use their tools"
- "Hands-on projects that involved current issues"
- "I love deductive reasoning and using problem solving skills"
- "Military science was the most hands on. I believe. Also, everything that was taught could be applied to real life."
- "I can do anything if I put my mind to it"
- "My favorite part of the Jumpstart program was the investigation gathering, evidence, and all of the different lab work"
- "I love the UCCS programs in general"
- "This introduces me to new science methods"

Parent comments regarding PIPES Student Programs:

- "My daughter enjoyed the program so much that she continues to ask me when the next one will be. She is set on attending every program that she can. I am excited to see her so enthused about learning!"
- "Great experience, she enjoyed the class (biotechnology). Would love to see more options (additional dates)."
- "My child was really excited when he came home from PIPES. He really liked the program and was amazed by the things they learned and made in science. He's excited about attending more PIPES programs in the future."
- "The Sports Training Camp opened up a new perspective in regards to science. Excellent for my daughter."
- "[Participant name] had such a great time at STEM. He's asked me a dozen times when he can participate again…I can't thank you enough for putting on such a wonderful program."
- "This was a wonderful experience for my son. He had not felt that he could be successful in science. He especially enjoyed the robotics."
- "The most interesting was the field trip to the composting farm. He told us all about the "farming" and the mycelium. He was so interested that we bought a composting bin so he could "grow" rich soil. He continues to think how this could be turned into a community service project. The week--and especially the field trip--was inspiring to him and sparked a lot of interest."
- "[Participant name] enjoyed learning about the water purifications process. And her music pen is still working. She really enjoys it. She is so proud of it.
- "He absolutely loved it!!! The hands-on experience is everything!!"

Teacher comments regarding PIPES Educator Programs:

- "Great!! We did wonderful activities."
- "The sharing of both their [instructors] educational philosophies and techniques were invaluable!"
- "OUTSTANDING! I was extremely intimidated by physics before this experience; Doug did a wonderful job helping me feel comfortable and confident in learning and teaching physics.
- "Very beneficial program"
- "THANK YOU for the opportunity to participate. I am amazed how much I learned in this past 2 weeks. The team was very dedicated to helping us to be successful and I appreciate their passion and commitment."
- "It was a great professional development opportunity! I really enjoyed it."

- "I really enjoyed the Math Circle and felt it was very beneficial. I received engaging activities for my students to use in my classroom. I liked the concept of sharing ideas with other Math teachers and having lots of resources to help with Math. I feel that my understanding of Problem Solving has grown which will make my students more successful."
- "This was one of the most challenging, rewarding and valuable experiences I've had in my math career. The time in the mountains made me feel special and valued. It engaged my interest and learning. I'm glad we had a chance to get to know each other and feel "safe" learning together. I feel like I have grown and have become so much better equipped to teach my students to persevere in problem solving. Thank you! Thank you!"

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14. ABSTRACT
The Center for Science, Technology, Engineering, and Mathematics Education (CSTEME) was one of four sponsored centers through the National Institute of Science, Space, and Security Centers located on the University of Colorado, Colorado Springs (UCCS) campus and initially funded by the U.S. Air Force Office of Scientific Research (AFOSR). Through its Partnership in Innovative Preparation for Educators and Students (PIPES) program, CSTEME responded to the lagging performance and retention of students in science and math through innovative and supportive partnerships with parents, educators, and professionals. Leveraging on-campus faculty as well as the technology and military industries that are so prevalent in the Pikes Peak area, CSTEME aspired to attract and encourage a new generation of creative, artistic, and innovative students to solve our future problems related to science, technology, engineering, and mathematics (STEM). Underlying all PIPES activity was a solid evaluation framework that measured student interest and retention in STEM subjects through longitudinal tracking of students from 6th through 12th grade and assessing teachers who completed PIPES professional development programs over 4 years.

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