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PARTNERSHIP IN INNOVATIVE PREPARATION FOR EDUCATORS AND STUDENTS (PIPES)

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UNIV OF COLORADO

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Final Report

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14. ABSTRACT
Through the Partnership in Innovative Preparation for Educators and Students (PIPES) program, the Center for STEM Education at the University of Colorado Colorado Springs responded to the lagging performance and retention of middle and high school students in science and math through the use of 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, the PIPES program 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). 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. 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.

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FINAL PERFORMANCE REPORT

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Program Manager:	Dr. Neville Thompson

Dr. Gene Abrams, Principal Investigator
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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

Through the **Partnership in Innovative Preparation for Educators and Students (PIPES)** program, the Center for STEM Education at the University of Colorado Colorado Springs responded to the lagging performance and retention of middle and high school students in science and math through the use of 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, the PIPES program 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). Funding received from AFOSR in 2007 was used to initiate the PIPES effort. The current award (FA9550-09-1-0713), which concluded in September 2013, had as its goal the "further support and extension of the PIPES program efforts".

PIPES 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 had impacted 1,480 students, 63 science teachers, and 103 math 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. When the combined impact of teacher and student programs is explored the PIPES program both directly and indirectly reached over 23,000 students in the Pikes Peak region and throughout Colorado.

Underlying all PIPES activity was a solid evaluation framework that measured student interest in STEM subjects and persistence in STEM study through longitudinal tracking of students from 6th through 12th grade. Additionally, teachers who completed PIPES professional development programs were surveyed 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.

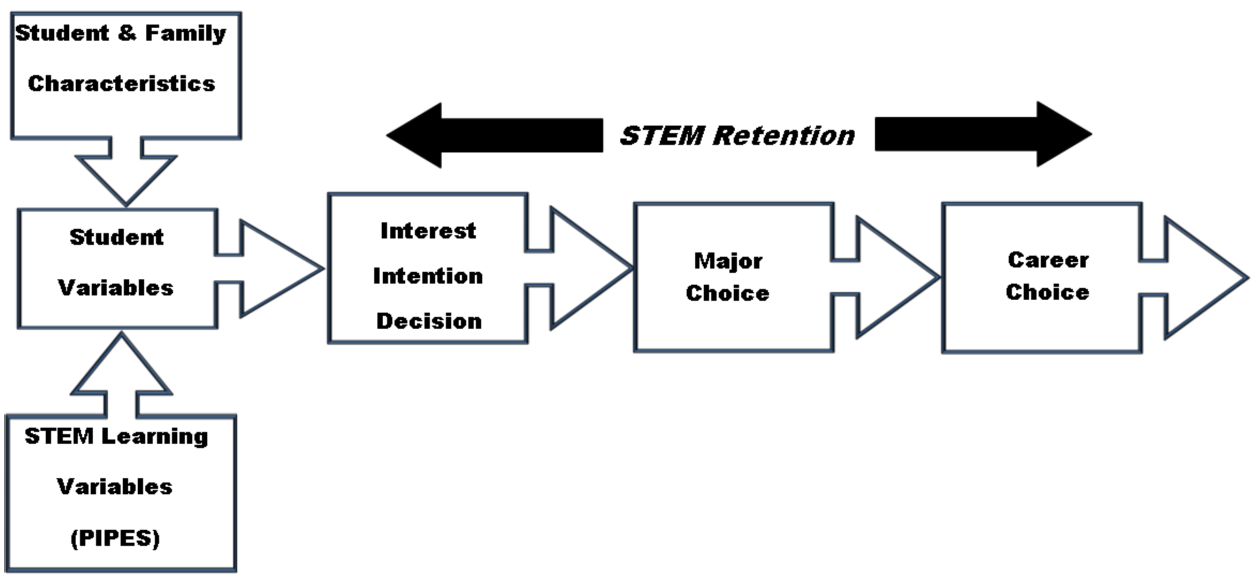
This evaluation framework measured changes in student attitude toward STEM, their STEM career interest, and their intention to enter a STEM field. Additionally, STEM retention, and academic achievement in STEM subjects were evaluated. The results of this research provided crucial guidance in developing 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, but 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. 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 based on a rigorous review of the STEM educational research 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 which 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 & Mitchell, 1993) constructivist pedagogies (Lombardi & Oblinger, 2007) requiring collaboration with peers within a distinct learning context that students can easily relate to (Stanley & Waterman, 2005). The longitudinal nature of student and parent support was found to substantially increase student retention and interest in STEM content (George, 2006).

Figure 1 - PIPES Student Research Model



PIPES Evaluation Questions:

This project was designed to address the following evaluation questions:

- To what degree did PIPES student programs improve student confidence and motivation to pursue advanced STEM courses in high school?
- To what degree did PIPES student programs improve student confidence and motivation to pursue a STEM major in college?
- To what degree did PIPES student programs improve student confidence and motivation to pursue a STEM career?
- To what degree did PIPES programs increase the number of students declaring a STEM major after high school graduation?

PIPES Evaluation Model Variables:

This study utilized two constructs as predictor variables. These constructs included:

- **Student and Family Characteristics** – demographics (e.g., 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 outcome variables included:

- **Student Variables** – 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.
- **Student Major Choice –** whether or not a PIPES student selected a STEM major after graduation from PIPES.

Details on the specific constructs and survey instruments used can be found in Appendix A.

PIPES Programs:

The PIPES model provided 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 hours of peer collaboration, lab and field work, engineering design, and innovative problem solving alongside graduate level facilitators, 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:

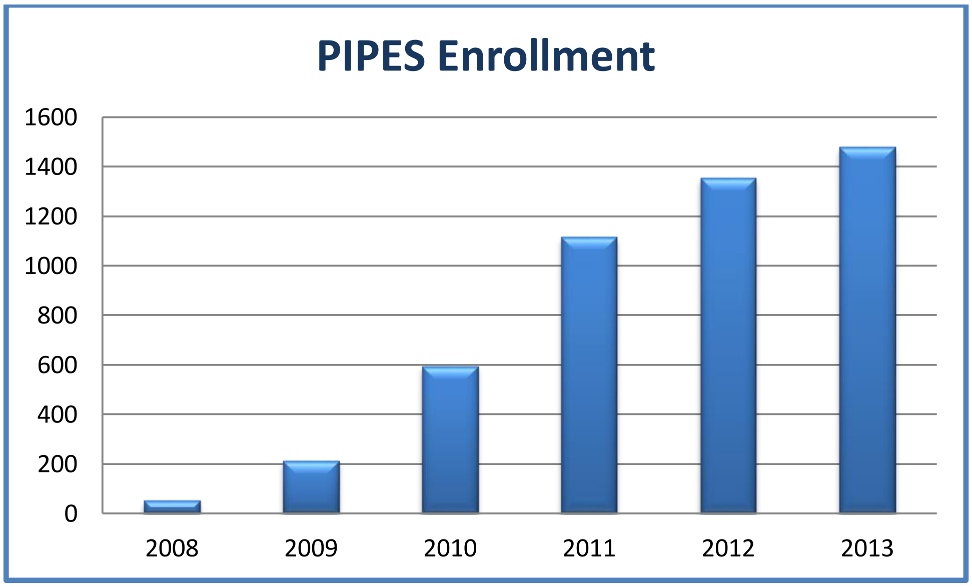
- **Mind Quest:** A series of middle and high school workshops held four times per academic year covering a variety of STEM topics (e.g., computer science, engineering, food science, and biotechnology).
- **STEM in Real Life:** A two-day summer camp for middle school students designed to allow each participant 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 STEM:** 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.
- **Bridge to Engineering:** A week-long summer camp for high school students interested in pursuing an engineering major after graduation. Students work in collaborative teams to address an engineering design challenge. Student test their designs in the field then present their findings to a panel of industry experts. The design challenges encompassed all major engineering disciplines.
- **Math Bridge:** The capstone experience for PIPES high school students which offered students the opportunity to assess their math skills and remediate any deficiencies.

DESCRIPTION OF PIPES STUDENTS

Student Numbers and Demographics:

The number of participating students started at 53 in 2008 and grew to 1,480 PIPES-enrolled students in 2012-13 (see Figure 2). 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 (46%) were students who will be the first in their families to attend college (known as first-generation students).

Figure 2 – PIPES Student Yearly Enrollment Growth



PIPES Student Demographics (*n* = 1,480)

HISPANIC

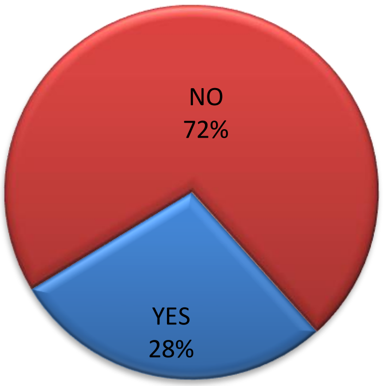


Figure 5

1st GENERATION

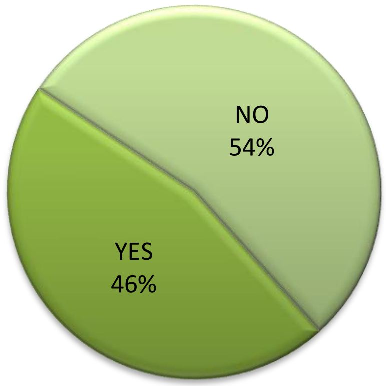


Figure 4

FAMILY INCOME

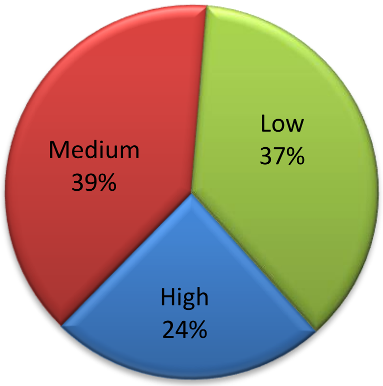


Figure 3

RACE

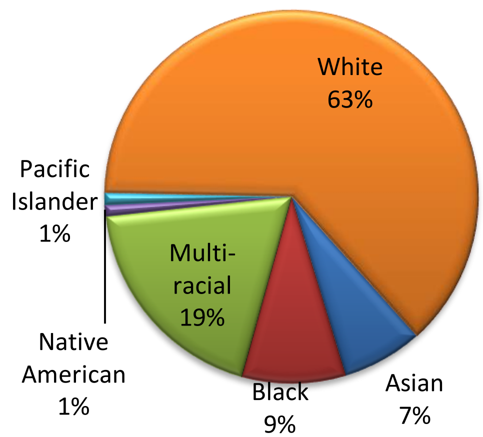


Figure 6

GENDER

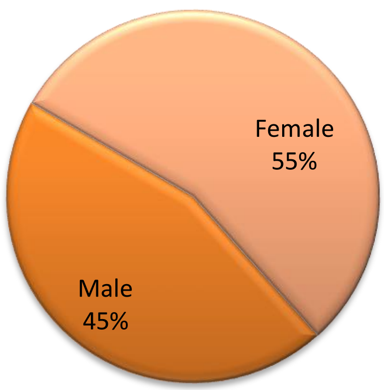


Figure 7

RESULTS

PIPES Evaluation Question Results:

Through the generous support of AFOSR, the PIPES project produced significant results as analyses showed increased interest and confidence to pursue advanced STEM classes in high school, STEM courses in college, a STEM major, and a STEM career.

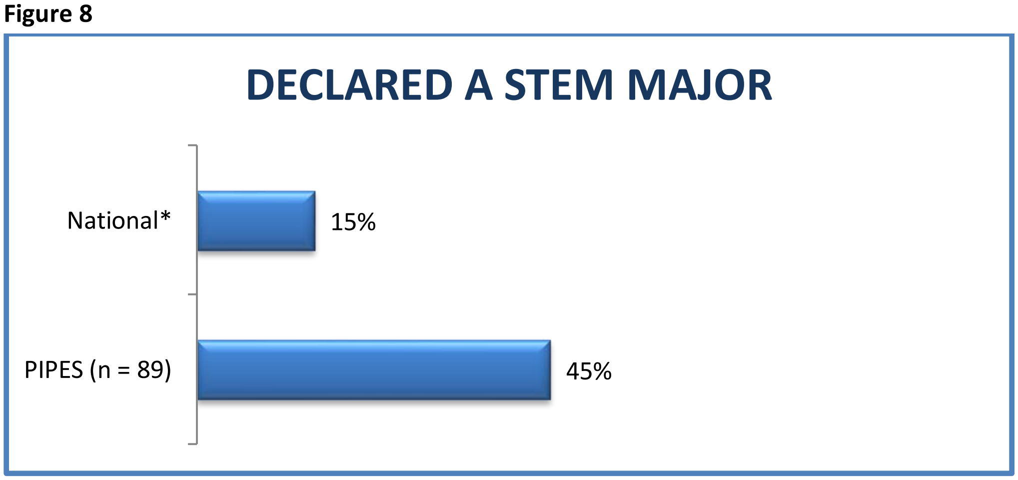
These data were produced from two types of student surveys. The first type was a longitudinal survey given before PIPES involvement (pre-survey) and after each year of PIPES involvement (post-survey). The second type was a retrospective pre/post survey given after each camp and workshop. In this survey, students recorded their thoughts, feelings, and attitudes toward STEM before the camp then after the camp. Paired samples *t*- tests were conducted to evaluate the impact of the camp or workshop on student perception, motivation and confidence linked to the desire to pursue STEM further in high school and college.

Qualitatively, comments from students, parents, and teachers showed a high level of enthusiasm for PIPES programs (see participant comments, Appendix 3). Post-program survey results revealed that PIPES programs had a positive influence on students' internal motivation to study STEM, student confidence in their ability to do STEM courses, their general STEM knowledge, and achievement (see Figures 8-11). These finding indicated that the PIPES model of student outreach is an effective program in increaseing students' interest in STEM courses and careers.

Question 1: *To what degree did PIPES programs increase the number of students declaring a STEM major after high school graduation?*

Longitudinally, 6% of the PIPES students (58% male, 42% female) have graduated high school. Over 83% of these students went on to study in college (94% of which in Colorado), higher than the national percentage (68% in 2011; Bureau of Labor Statistics, 2012) and in Colorado (63% in 2008; The National Center for Higher Education Management Systems, 2013). Additionally, 59% of the students who went to college attended the University of Colorado Colorado Springs (UCCS), with an additional 19% attending Pikes Peak Community College (a UCCS pipeline). Further, ***45% of the students who entered college declared a STEM major, triple the national rate*** (15% in 2006; National Center for Education Statistics, 2009).

Figure 8

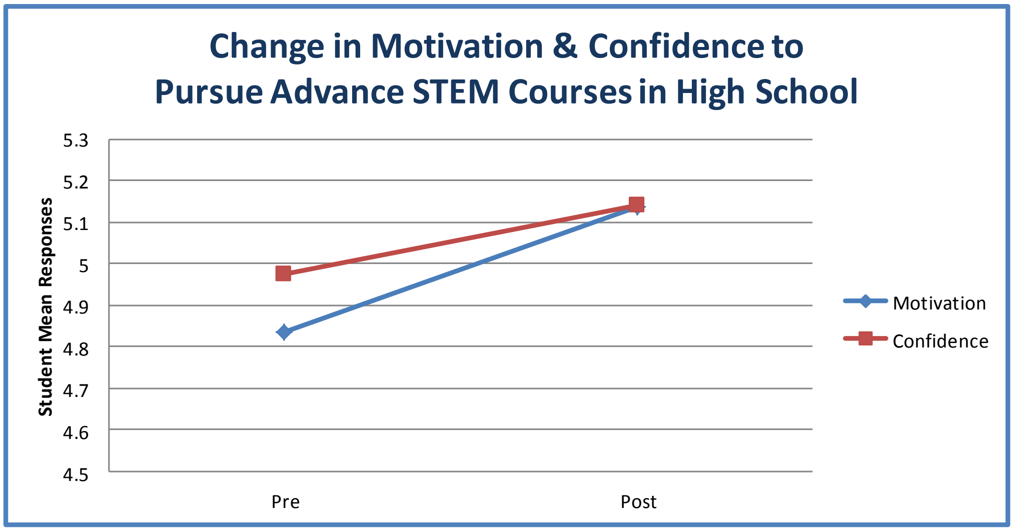


*National Center for Education Statistics, 2009

Question 2: *To what degree did PIPES student programs improve student confidence and motivation to pursue advanced STEM courses in high school?*

PIPES camps and workshops significantly improved student motivation to pursue advanced STEM courses in high school. Additionally, PIPES programs improved student confidence that they could succeed in these advanced courses (see Figure 9). Both of these measures are predictors of future STEM retention and success after high school graduation.

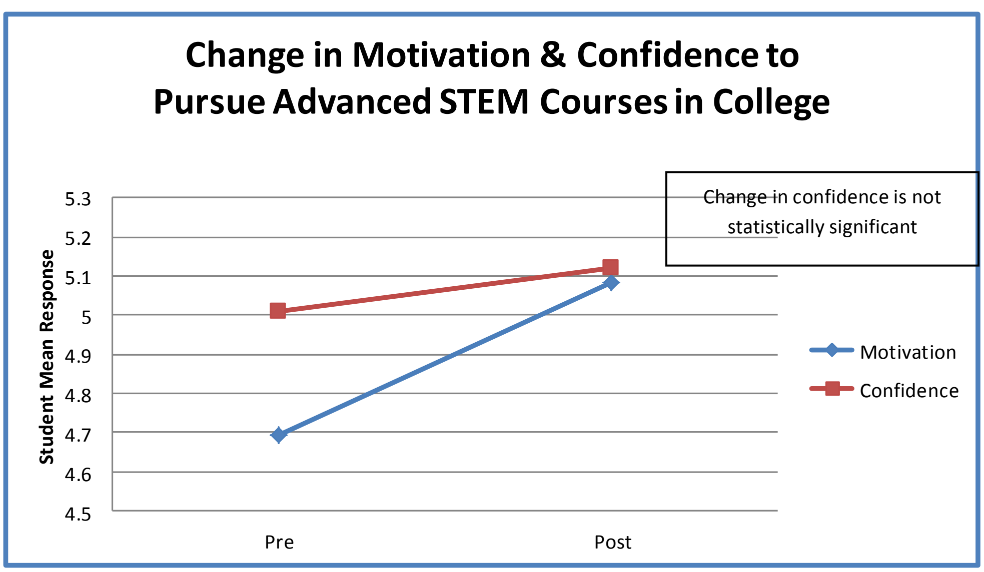
Figure 9 (n = 69, p < .01)



Question 3: *To what degree did PIPES student programs improve student confidence and motivation to pursue a STEM major in college?*

PIPES camps and workshops significantly improved student motivation and confidence to pursue a STEM major in college. Additionally, the number of students planning on majoring in a STEM field significantly increased pre to post (see Figure 10).

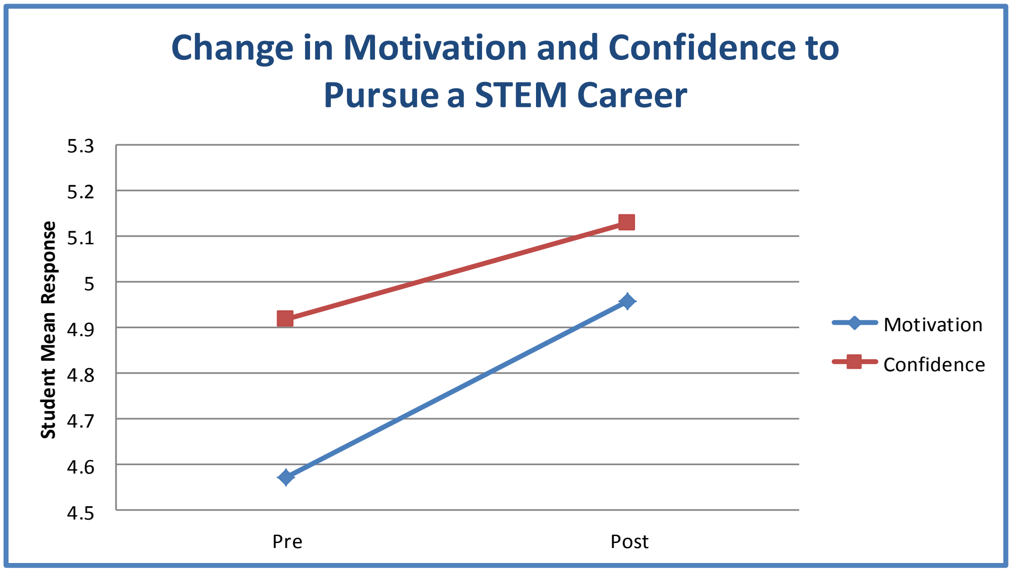
Figure 10 (n = 69, Motivation significant at p < .01 level)



Question 4: *To what degree did PIPES student programs improve student confidence and motivation to pursue a STEM career?*

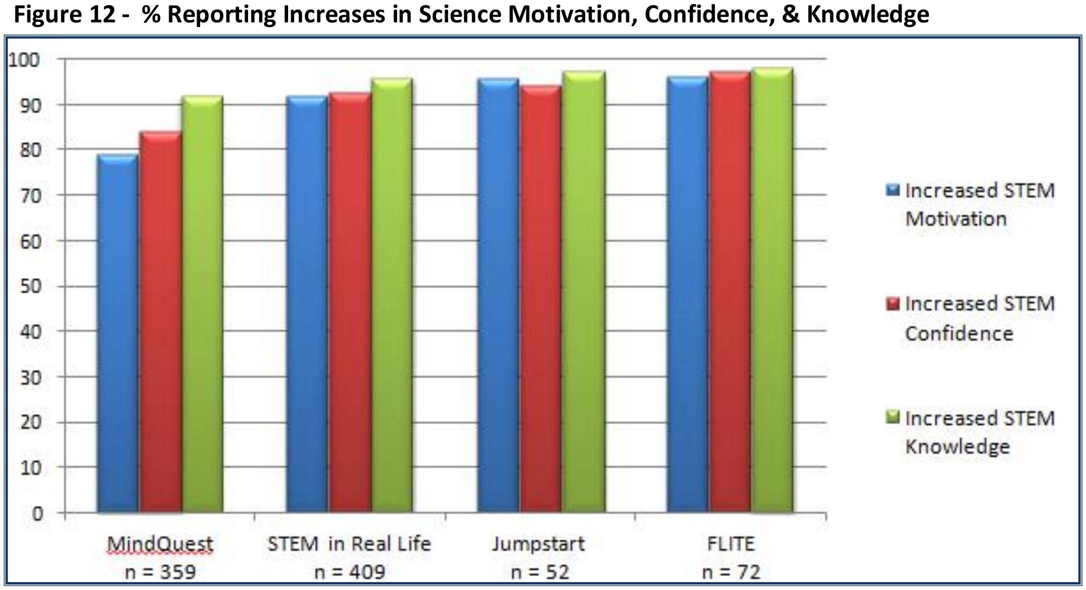
PIPES camps and workshops significantly improved student motivation to pursue a STEM career. However, no significant change was observed in student confidence that they could succeed in a STEM career. This finding is relatively common in previous studies and is partially due to the student coming to a deeper understanding of the challenges of a STEM career (see Figure 11).

Figure 11 (n =70, p < .01)



Per program, PIPES was successful in increasing student motivation, confidence, and knowledge in STEM. Overall, each program and camp in the PIPES menu of offerings produced an increase in these three measures from 6th – 12th grades (see Figure 12).

Figure 12 - % Reporting Increases in Science Motivation, Confidence, & Knowledge



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). 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.

PIPES Teacher Program Evaluation Questions:

Question 1: To what degree did participation in the PIPES Science Educator Academy (PSEA) improve teachers' confidence in using inquiry, STEM-based practices in their science classrooms?

Question 2: To what degree did participation in the PIPES Pikes Peak Math Teacher's Circle (PPMTC) improve teachers' confidence and ability to use inquiry, problem-based practices in their math classrooms?

PIPES Evaluation Model Variables:

The predictor variable used in this evaluation was whether a teacher had completed the PIPES professional development program. Additional demographic data were collected on the teacher and school for future analysis.

The constructs used as the outcome variables included:

Teacher self-efficacy – the degree to which the teacher feels they are able to accomplish specific inquiry learning tasks with their students.

Teacher confidence – the degree to which the teacher feels they are able to use inquiry learning strategies in their classrooms resulting in a positive outcome.

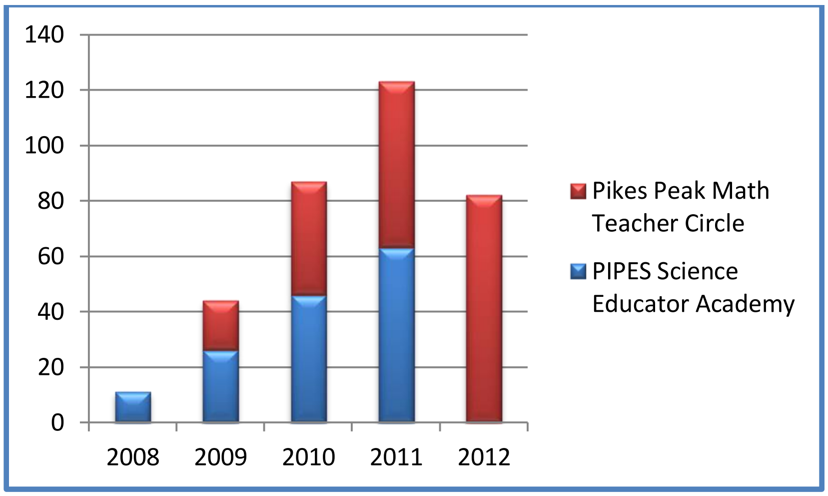
Teacher instructional practice – the degree to which the teacher applies the inquiry strategies in their classroom.

Description of PIPES Teachers

Teacher Numbers:

The number of participating teachers began in 2008 with 15 science teachers, each having an impact on 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 13- next page). By 2012, PIPES programs had instructed 82 math teachers and 63 science teachers, for a total student impact in excess of 20,000 students annually. 32% percent of the teacher who participated taught in schools in which the majority of students qualified for free and reduced lunch services. 55% of the teachers who participated taught in schools with minority student populations of at least 30%.

Figure 13 Teacher Participation

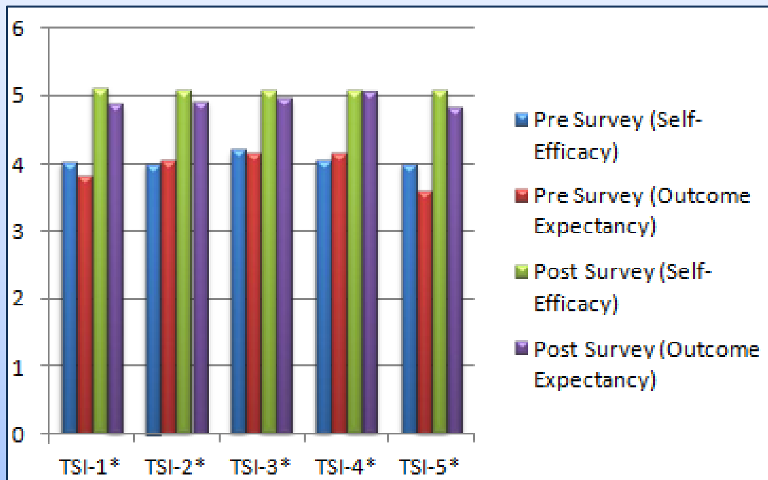


PIPES Teacher Results:

Since the first PIPES professional development programs for STEM educators in 2008, early data indicated that the PIPES model improved science and math teachers' confidence in using inquiry-based methods.

Among science teachers served, statistically significant increases were observed in the science teachers' confidence to teach science content using inquiry-based methods after being in the program for one year. Additionally, science teacher reported an increase in confidence that implementing their newly developed teaching skills would increase student achievement outcomes (see Figure 14 – next page).

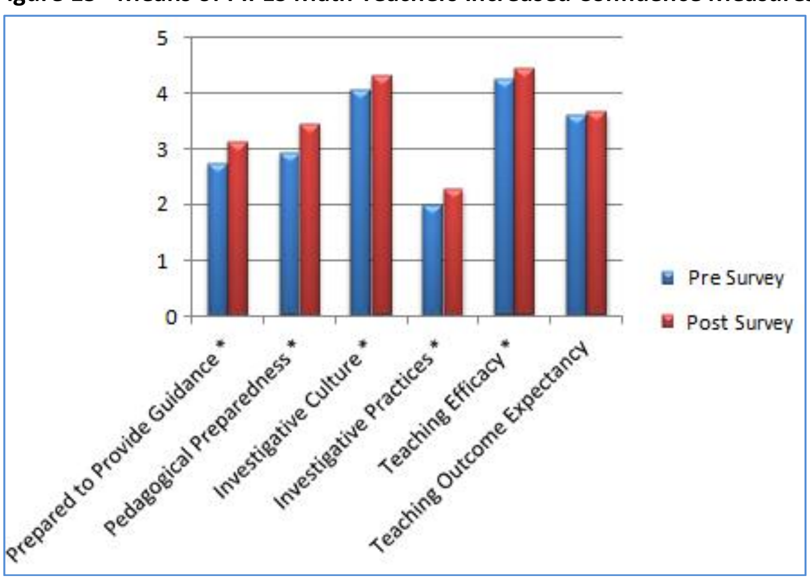
Figure 14



(**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

Among math teachers served, statistically 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 15). 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 15 - Means of PIPES Math Teachers Increased Confidence Measures



***Denotes Statistically Significant Differences (n = 80)**

Overall, the PIPES teacher development programs significantly improved the confidence and ability of teachers to use inquiry-oriented approaches in their classrooms. These approaches are important to teaching STEM in a meaningful and applied way that has been shown to increase student engagement in STEM subjects and retain student interest in STEM majors and careers.

Interestingly, the work that began with the AFOSR funding is being sustained through the use of PIPES teachers becoming STEM education experts by serving as instructors for PIPES student workshops. Additionally, many PIPES teachers have moved into STEM leadership roles in their schools and districts. By PIPES teachers becoming STEM leaders in the community, the initial investment by AFOSR has produced tangible dividends toward sustaining the use of STEM methods in classrooms across the region.

FUTURE DIRECTION & SUSTAINABILITY

PIPES Dissemination and Replication:

The PIPES research team has made concerted efforts to disseminate the findings produced by the PIPES project through publications and presentations around the nation (see Appendix 4). Additionally, replication of PIPES programs has always been an important goal in the program model. Through the successes experienced at UCCS, PIPES has been able to work with many other STEM organizations across the state to support the establishment of STEM centers based on the PIPES model. Many new opportunities for collaboration, partnership, and funding have emerged because of the generous support by AFOSR to establish the PIPES model. The work that began 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. Current examples include:

- For the past three summers, 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.
- STEM programs in Pennsylvania, Connecticut, and Colorado have used the PIPES program as a model for their own STEM program structure. In many cases, these centers have used PIPES curriculum developed with AFOSR funding for their own camps.
- PIPES STEM curriculum are used in a large number of classrooms across the Colorado Springs region. Schools are beginning to adopt PIPES curriculum to support STEM electives and classes embedded in the school day.
- Many non-profit outreach programs are using PIPES curriculum to support their own STEM outreach.
- The quality of the PIPES program has generated research partnerships with the University of Wyoming, Cornell University, and California Institute of Technology (CalTech).

PIPES Future Initiatives:

Due to the generous support of AFOSR, the Center for STEM Education (CSTEME)at UCCS has become a significant contributor to the STEM conversation around the state. Based on the initial funding for programs, research, and training through AFOSR, CSTEME is now involved in several STEM program evaluations, curriculum development projects, and STEM leadership organizations. Additionally, the initial success of the PIPES program has enabled CSTEME to generate over $300,000 in program and research funding. Partnerships include the Harris Foundation, ExxonMobil, the Anschutz Foundation, the Women's Foundation, the Colorado Governor's Office of Information Technology, and others. The PIPES program, through CSTEME continues to grow and thrive thanks to the generous funding of AFOSR in starting the center at UCCS.

Changes for Future Success:

A project of the scope and size of the PIPES project creates many challenges and opportunities to learn from mistakes. Though the project has been, and continues to be a success, there have been many lessons learned from the process of establishing a regional and state hub for STEM learning. First, the importance and difficulty of managing a longitudinal study is significant. The longitudinal PIPES dataset continues to be a work in progress as the research team learns how to best encourage PIPES students to complete yearly follow-up surveys. Student retention in the PIPES program is very high at 63% of students returning for more than two programs. The difficulty arises in engaging families to fill out the follow-up surveys at home. Additionally, preventing survey fatigue among students is a significant issue. The primary solution being explored is the expanded use of retrospective pre/post surveys to minimize the number of survey instances and shortening the survey using imputed values in order to gain the necessary level of student data for analysis. Second is data management. Currently, the CSTEME research team is working on transitioning PIPES data into a relational database that can be easily queried and shared among other researchers. Third, the PIPES dataset still has a significant self-selection bias on the data. Over time, CSTEME personnel have been able to minimize this bias through partnerships with school districts and pre-collegiate development organizations. In both of these examples, students are required to attend the STEM event regardless of their interest. However, many PIPES students self-select into the program, biasing the results toward the positive, creating the possibility of a type-I error. The CSTEME research team continues to explore ways of achieving quasi-experimental conditions related to STEM research while minimizing confounding variable effects.

In summary, because of the AFOSR's substantial investment in the PIPES program and CSTEME, there now exists a robust STEM center serving Colorado through STEM programs, outreach, research, and evaluation. Without the initial investment of AFOSR funds, this center would not be in existence nor would it have achieved the level of sustainability that it currently enjoys. When the PIPES project began, STEM education was just emerging into the nation's collective consciousness as a significant need for the future economic viability of the country. Now, at the close of the project, STEM education is a well-known and oft talked about issue in the US. The timing of the AFOSR funding to establish PIPES and CSTEME was superb in that it provided a means to examine various STEM educational strategies while establishing a robust longitudinal database that will serve educational researchers for years to come. All of these outcomes are a direct result of the funding provided by AFOSR through the PIPES project. With long-term sustainability in place, that initial investment will have a large payoff for years to come.

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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!

Arduino – Unleash your inner inventor by learning how to program a microcontroller and build circuits for robotics, high tech art, wearable electronics, and all sorts of smart devices. Learn how to program in C++ an breadboard your own circuits

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!”

APPENDIX 3 – PROJECT SURVEY INSTRUMENTS

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).

Sources of Math Self-Efficacy were evaluated by adopting the 24-item Sources of Middle SchoolMathematics Self-Efficacy Scale (Usher & Pajares, 2009) for use in this study. This scaleconsisted 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).

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.

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.

Attitudes toward Science and Career in Science were measured with a 16-item survey designed for use in the current study.

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.

Peer Encouragement was assessed with a 7-item scale adapted from the Friends' AttitudesToward 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.

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 Maresreported adequate internal reliability (.79).

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.

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.

Math / Science Aptitude, defined by scores on standardized tests (i.e., CSAP/TCAP, ACT)were obtained from student transcripts.

Math / Science Achievement was defined as students' grade in science/math class at the end of each grading period.

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."

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.

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.

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.

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.

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 post-testing was .79.

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 Teaching Science as Inquiry (TSI) was validated by Smolleck, Sembal-Saul, and Yoder (2006); and L. A. Smolleck & Yoder (2008) to measure teacher self-efficacy in reformed settings. 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 studyprovided correlation coefficients for each of the eight composites greater than 0.60. Based on these findings, the LSC teacher questionnaire was found to be a valid and reliable measure of teachers' attitudes, preparedness, and classroom practices.

APPENDIX 4 - PIPES PUBLICATIONS AND PRESENTATIONS

Publications:

Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2012). Professional development in inquiry science teaching: Self-reports, interviews, and observations. Manuscript submitted to Science Education (rejected from JRST).

Carpenter, D., & Clayton, G. A. (2012). First generation pre-collegiate, gender, sources of self-efficacy, and academic achievement in secondary school students. Manuscript submitted

Decker, L. L., & Marle, P. D. (2012). An evaluation of a science educators' academy: Benefits of inquiry-based teaching for educators and their students. Manuscript in preparation.

Kuehler, C. P., Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2012). Gender differences in high school students' interest and attitudes: Scenario-based STEM education. Manuscript submitted for publication.

Marle, P. D., & Decker, L. L. (2012). An evaluation of a math teachers' circle program: Inquiry-based pedagogy in practice. Manuscript in preparation.

Marle, P. D., & Decker, L. L. (2012). Replication of a summer STEM camp: A comparison of urban and rural camps. Manuscript in preparation.

Marle, P. D., Decker, L. L., Kuehler, C. P., & Khaliqi, D. H. (2012). Equitability for middle and high school students in a summer STEM camp. Manuscript submitted for publication.

Marle, P. D., Decker, L. L., Taylor, V., Fitzpatrick, K., Khaliqi, D., Owens, J. E., & Henry, R. M. (2012). CSI-chocolate science investigation and the case of the recipe rip-off: Using forensic science to engage students. Manuscript submitted for publication.

Carpenter, D., & Khaliqi, D. H. (2013). Examining the construct validity of the Student Subjective Science Attitude Change Measures (SSSACM). Manuscript submitted for publication.

American Institute of Mathematics. (2013). Research spotlight. Investigations in the classroom: Study finds MTC participation leads to more inquiry-based teaching. *MTCircular, Winter,* 11.

Presentations:

Decker, L. L., Braun-Sand, S., Haggren, W., Fitzpatrick, K., & Marle, P. D. (2013, April). *What is the influence of family in STEM persistence? Lessons from successful K-16 experiences.* Panel discussion presented at UCCS Diversity Summit, Colorado Springs, CO.

Decker, L. L., Marle, P. D., & Khaliqi, D. H. (2013, April). *Fueling the STEM pipeline: Comparing PIPES students to regional and national college matriculation.* Poster session presented at UCCS Mountain Lion Research Day, Colorado Springs, CO. .

Khaliqi, D. H., Marle, P. D., & Decker, L. L. (2013, April). *Findings from a Math Teachers' Circle: Past, present, and future directions.* Paper session presented at National Council of Teachers in Mathematics Annual Conference, Research Pre-session, Denver, CO. .

Khaliqi, D. H., Marle, P. D., Decker, L. L., & Fitzpatrick, K. (2013, April). *Broadening participation in science, technology, engineering, and math (STEM): Best practices and future considerations.* Panel discussion presented at UCCS Diversity Summit, Colorado Springs, CO.

Pugh, J., Marle, P. D. Decker, L. L., & Khaliqi, D. H. (2013, April). *Jumpstarting STEM education: Sparking attitudes and intentions in underserved student populations*. Poster session presented at Colorado Springs Undergraduate Research Forum, Colorado Springs, CO.

Szarka, A. K., Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2013, April). *Self-efficacy and other influences of STEM careers: Investigating differences among underrepresented students*. Poster session presented at Colorado Springs Undergraduate Research Forum, Colorado Springs, CO.

Fitzpatrick, K. (2012, November). *How to effectively implement inquiry in the classroom*. Paper session presented at Colorado Science Conference, Denver, CO. .

Khaliqi, D. H. (2012, November). *STEMify your instruction*. Paper session presented at Colorado Science Conference, Denver, CO. .

Khaliqi, D. H., Marle, P. D., & Decker, L. L. (2012, November). *Teachers STEMing out! Lessons learned from a university and K-12 educator collaboration.* Paper session presented at School Science and Mathematics Association Annual Convention, Birmingham, AL. .

Khaliqi, D. H., Marle, P. D., & Decker, L. L. (2012, November). *A new survey to measure alignment to inquiry in curricula*. Paper session presented at Rocky Mountain Educational Research Association Annual Conference, Las Cruces, NM. .

Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2012, November). *An inquiry into Math Teachers' Circle: Findings from two year-long cohorts*. Paper session presented at School Science and Mathematics Association Annual Convention, Birmingham, AL.[1]

Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2012, November). *Student and instructor perceptions of alignment to inquiry in curricula*. Poster session presented at Rocky Mountain Educational Research Association Annual Conference, Las Cruces, NM.

Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2012, August). *The role of psychology in facilitating growth in STEM (Science, Technology, Engineering, and Math).* Poster session presented at the American Psychological Association Annual Convention, Orlando, FL.

Clayton, G. A., Marle, P. D., & Decker, Lisa L. L. (2012, April). *Confirmatory factor analysis for sources of math self-efficacy.* Poster session presented at University of Colorado Colorado Springs Mountain Lion Research Day, Colorado Springs, CO..

Decker, L. L., Taylor, V. R., Marle, P. D., & Khaliqi, M. A. (2012, April). *Fixing leaky pipes: Bringing STEM programs to a rural community.* Poster session presented at University of Colorado Colorado Springs Mountain Lion Research Day, Colorado Springs, CO.

Marle, P. D., Decker, Lisa L. L., Khaliqi, D. H., & Benson, J. J., (2012, April). *Boosting students' STEM interest: Reforming science teachers' pedagogical approaches.* Poster session presented at University of Colorado Colorado Springs Mountain Lion Research Day, Colorado Springs, CO.

Pugh, J., Marle, P. D., Decker, L. L., & Khaliqi, D. H. (2012, April). *Chocolate as science: Producing equitability utilizing a scenario-based STEM camp for middle and high school students.* Poster session presented at the Colorado Springs Undergraduate Research Forum, Colorado Springs, CO.

Szarka, A. K., Marle, P. D., Decker, L. L., Khaliqi, D. H., & Abrams, G. A., (2012, April). *Surge in educators' self-efficacy for teaching math follows participation in Pikes Peak Math Teachers'*

[1] *Featured on the American Institute of Mathematics,* MTC website, <http://www.mathteacherscircle.org/about/outcomes.html>

Circle. Poster session presented at the Colorado Springs Undergraduate Research Forum, Colorado Springs, CO

Khaliqi, D. H. (2012, January). *Creating STEM resilient students.* Paper session presented at Educating Children of Color Conference, Colorado Springs, CO.

Khaliqi, D. H. (2012, January). *Creating resilience to pursue STEM*. Paper session presented at Emerging Leaders Symposium, Colorado Springs, CO.

Decker, L. L. (2011, November). *Impact of repeated exposure to inquiry based STEM educational workshops on K-12 students.* Paper session presented at School Science and Mathematics Association Annual Convention, Colorado Springs, CO. .

Fitzpatrick, K. (2011, November). *Why so few? Breaking through barriers for women and girls.* Paper session presented at Colorado Science Conference. .

Fitzpatrick, K. (2011, November). *Getting girls to blossom from the STEM up*. Paper session presented at Colorado Science Conference, Denver, CO. .

Khaliqi, D. H. (2011, November). *Students saving the world: Using scenario-based learning to deepen student engagement*. Paper session presented at School Science and Mathematics Association Annual Convention, Colorado Springs, CO. .

Khaliqi, D. H. (2011, November). *Using an Arduino microcontroller for more than you would think.* Paper session presented at Colorado Science Conference, Denver, CO. .

Marle, P. D. (2011, November). *Influence of parental involvement by gender on student outcomes in STEM*. Paper session presented at School Science and Mathematics Association Annual Convention, Colorado Springs, CO. .

Khaliqi, D. H. (2011, October). *Computer powered art.* Paper session presented at 21st Century Skills Symposium, Colorado Springs, CO.

Grassman, D. (2011, April). *What are effective ways of retaining students in STEM?* Paper session presented at the Colorado Springs Undergraduate Research Forum, Colorado Springs, CO.

Khaliqi, D. H. (2011, April). *Using an Arduino microcontroller for more than you would think.* Paper session presented at Career-Technology Educator Conference, Longmont, CO.

Marle, P. D., Kuehler, C., Decker, L. L., Khaliqi, D. H., & Abrams, G. (2011, April). *Meteors, robots, crime scenes, and chocolate: How PIPES uses innovation and imagination to grow students from the STEM up.* Poster session presented at University of Colorado Colorado Springs Mountain Lion Research Day, Colorado Springs, CO. .

Pugh, J., Endres, T. L., Grassman, D., Marle, P. D., & Decker, L. L. (2011, April). *Psychometric properties of the PIPES Science Outlook Survey (SOS)*. Paper session presented at the Colorado Springs Undergraduate Research Forum, Colorado Springs, CO. .

Fitzpatrick, K. (2010, November). *The power of a story in STEM education*. Paper session presented at Colorado Science Conference, Denver, CO. .

Khaliqi, D. H. (2010, November). *Robotics on the cheap.* Paper session presented at Colorado Science Conference, Denver, CO.

Khaliqi, D. H. (2010, November). *STEM and stories: Using problem based learning in informal STEM education.* Paper session presented at International STEM in Education Conference, Brisbane, Australia.

Kuehler, C., Cryer, L., & Sambrook, R. (2010, April). *Using an emergency management scenario for fostering resilience and encouraging students' interest in STEM fields*. Poster session presented at University of Colorado Colorado Springs Mountain Lion Research Day, Colorado Springs, CO.