ITEAMS: Increasing the Self-Identification for Girls and Underserved Youth in Pursuing STEM Careers

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ABSTRACT

We report early findings on the efficacy of a technology-based project in increasing self-identification for girls and underserved youth to self-select STEM (science, technology, engineering, and mathematics) careers. ITEAMS (Innovative Technology-Enabled Astronomy for Middle Schools) – an out-of-school-time program with online, robotic telescopes as its central focus – targets girls and minority students underrepresented in STEM-related vocations. The participating students attend urban schools in Eastern Massachusetts. ITEAMS' twofold goal is to: a) provide inspiration for the participants to pursue STEM careers, and b) increase the students' mastery of foundational subject matter so they are prepared for the rigor of further STEM study. We use an online system for surveys and assessments, the former to capture attitudinal changes about career choices, and the latter to assess the students' subject matter knowledge. Participating students take pre-, intermediate, and post subject-matter tests and career-interest surveys. While we find statistically significant gains in subject matter knowledge free of gender, race, or school bias, we also find girls profess less interest than boys in STEM careers as early as grades five and six, although other attitudinal indicators suggest ways to reverse that trend.

Keyword: STEM Careers, Career Interest, Technology Education, Out-of-School-Time, Robotic Telescopes, Online Assessment.

BACKGROUND

The ideas and skills of the nation's populace have always been its most important assets. In an increasingly technological world the value of these assets will depend significantly on the effectiveness of our science, technology, engineering, and mathematics (STEM) education. As the world has become immersed in an era evermore steeped in scientific and technological savvy and ingenuity, many Americans have become increasingly concerned about the nation's ability to compete on a global level. If the U.S. is to remain a leader among nations, the need for a highly-qualified STEM workforce and scientifically literate population will increase and continue to grow. This workforce will have to be of both adequate size and capability, as well as innovative, in order to stay abreast of the rest of the world in all the STEM fields. Policy makers and educators realize that the size of the STEM workforce can only grow by attracting more girls and underserved youth. To do so will require students to have the foundational knowledge to persist in STEM courses and to eventually choose to pursue a STEM career. As a result, inspiring students to master the necessary subject matter and encouraging them to choose a STEM career has become the focus of numerous formal and informal educational initiatives. Moreover, for girls in particular, to self-identify with STEM careers often means overcoming both environmental (e.g., encouragement of parent or teacher) and cultural (e.g., capability self-assessment) impediments [4].

Formally, states have implemented mandatory high-stakes exams to assess if students have mastery of basic subject matter knowledge (SMK). There have been numerous studies done or others that are in progress on SMK and high-stakes testing, some promoting and others decrying the exams. The tests reveal that certain student populations are showing adequate proficiency in SMK for promotion to the next level of schooling, yet the achievement gaps between white students and students of color persist. Of the many issues now being raised regarding the high-stakes exams, one is if they are equitable for all students, particularly for girls, English-language learners and students of color [5]. While these exam results are used for a variety of purposes and may show mastery of a subject, they cannot show SMK gain. One-time testing is incapable of pinpointing the practice that can lead a student from being a novice to mastery of a subject. Additionally, other work is currently underway to determine the effect of taking such exams, and how it can lead to or away from particular careers or earning potentials [5].

Informally, there has been a proliferation of out-of-school-time (OST) or free-choice learning programs. OST programs vary considerably. They are now the subject of rigorous research, with both federal institutions and private research facilities engaged in assessing the efficacy of OST programs. Most of this research is qualitative, and the positive benefits include better attitudes towards school, lower drop-out rates, more frequent completion of homework, as well as higher GPAs and higher standardized test scores [1, 2, 3, & 8]. The vast majority of studies completed to date focus on the immediate affect of OST, while our concern is both the immediate and future affects. Considering the positive influence OSTs have been shown to have on students, how early can educators introduce students to the possibilities of STEM careers through an OST program and inspire them to persist in that pathway? The timing is important. Tai, using National Educational Longitudinal Study (NELS) data, found that when students decide that they want to pursue a STEM career by the 8th grade, they are 3.4 times more likely to persist in STEM than classmates who at that same time decide differently [7]. This makes intervention at least by the early middle-school level imperative. If more students, especially girls and students of color, can be inspired to persist in the pursuit of a STEM career as they move through middle school, the nation's STEM workforce will grow and become more diverse.

ITEAMS (Innovative Technology-Enabled Astronomy for Middle Schools) is a National Science Foundation (NSF) funded project (NSF 08-33378) for grade 5-8 students, specifically targeting girls and underserved youth in OST programs. The student participants use robotic telescopes – designed, built, and maintained by members of the Science Education Department (SED) at the Harvard-Smithsonian Center for Astrophysics (CfA) – to acquire images of solar system and deep space objects. The robotic telescopes, known as MicroObservatory, are currently located in Massachusetts and Arizona. Our twofold ITEAMS goal is to: a) provide inspiration for participants to pursue STEM careers and, b) increase the students' mastery of foundational STEM subject matter. ITEAMS students control the SED's MicroObservatory robotic telescopes from within or outside of school, entering the target coordinates for solar system or deep space objects, exposure times, and filters to be used. The following morning the students receive an email message that the selected images are available for downloading and processing. We also include explorations in modeling, determining size and scale, light and color, and a range of other activities to investigate the technology of image acquisition, transmission, and processing. ITEAMS staff members build on the students' experiences with the robotic telescopes to expand their interest in additional areas of technology and STEM careers.

There are additional critical features with ITEAMS, including intensive professional development for project teachers, involvement of other university partners, participation by retired engineers and amateur astronomers, and parent involvement. ITEAMS teachers take part annually in at least 40 hours of professional development with a minimum of 20 additional hours of online support. There are both academic and non-academic partners, including: Harvard University's Earth and Planetary Sciences Department and the Initiative for Innovative Computing; the Amateur Telescope Makers of Boston (one of the oldest and largest amateur astronomy clubs in the nation); and the Retirees' School Volunteers Association (supported by Raytheon Corporation, and whose retired engineer members annually contribute more than 5000 hours of volunteer service to area schools). The non-academic partners volunteer at the schools, working with the students during the OST sessions. Participating students take field trips to high technology and robotic firms, science centers, and campus museums and research facilities. There is also programming for the students' families, both at the CfA and in their communities.

There are five eastern Massachusetts schools involved, one each in Boston, Lynn, and Fall River, and two in Cambridge. The two Cambridge ITEAMS sites are the Amigos and Benjamin Banneker Public Charter schools. Collectively the schools enroll about 650 students, predominantly from groups underrepresented in STEM careers, and on average 60-70% of these students qualify for free or reduced lunch. The demographic profiles for the Boston (Nathan Hale) and Lynn (Robert Ford) schools mirror those of the Cambridge sites; aggregately they have about 600 students. The Matthew J. Kuss School in Fall River, serves about 600 grade 6-8 students. One-third of the students are Hispanic, Asian, or African-American, with 95% of the school population living in low-income households.

We use a quasi-experimental, fine-grained research design to capture both the efficacy of the project on the STEM learning of students, and the interest and persistence of students in pursuing a career in a STEM field. To administer the concept inventories and surveys we use an online system and then analyze results using a paired-samples t-test and a repeated-measure ANOVA. We use the SED's distractor-driven multiple choice (DDMC) concept inventories to assess the STEM learning of participating teachers and students. Both groups are pretested in the fall and posttest in the spring. We also give the students an intermediate test in January. For both students and teachers we first use the inventories diagnostically, and only summatively with the posttest. We also conduct surveys to gauge student interest in STEM careers, and survey parents (in Spanish or Portuguese where appropriate) to assess their attitudes about having their children pursuing a STEM career. Students complete the career interest survey three times each year.

We report here on preliminary findings from the intermediate survey. When we submitted our ITEAMS proposal to the NSF we identified several research questions for the project, including the two that follow: 1) How effective is the project in enhancing student STEM understanding, and in creating and sustaining a link between STEM experiences and STEM careers for the participants? 2) To what degree do students perceive that the skills and conceptual knowledge developed in the project are potentially valuable for entering a STEM career or related vocation? The discussion that follows focuses primarily on the first question since to date we have only limited anecdotal data for the second question.

METHOD

One hundred forty students and 9 teachers from 5 schools are participating in the 2010-2011 school year phase of this project. At this writing students have taken two online SMK assessments: a pre- and intermediate. They have also taken the pre- and intermediate affective and career interest survey. The twenty-five question SMK assessment includes twenty DDMC items from our astronomy and space science item inventory and five demographic questions [6]. The content test includes items that are aligned to 6 middle-school space science National Science Education Standards. This year we piloted four questions aligned with National Educational Technology Standards on the pre- and intermediate SMK assessments. The same demographic questions are used on every assessment. We convert the student's birth date into an ID number that we then use to link data from the pre-, intermediate, and post-tests when assessing student gain in SMK. These data are analyzed using a paired-samples t-test and a repeated-measure ANOVA.

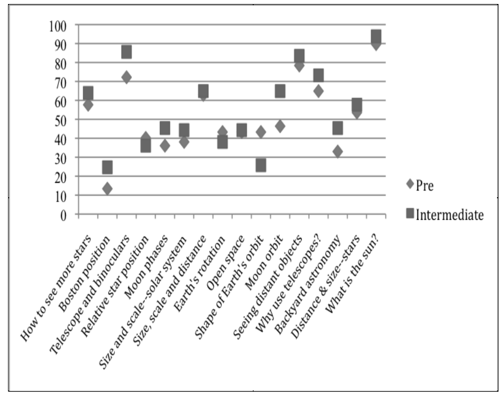
Students also completed the career interest and affective survey. This survey includes Likert-scale items measuring self-efficacy, self-identification and frequency of interaction with common technology. Additionally, students enter what they consider their first, second and third career choices (from a list of careers that includes "non-science other") at the time they are taking the survey (see Appendix A). Students also indicate, again on a Likert scale, the factors they consider important in choosing a career (see Appendix B). All of these data are analyzed with ANOVA, linked to the content data, and analyzed for significance using linear regression. We binned the career choices into STEM careers, medical/health careers, and other careers. We re-coded the data with a student's first choice coded as 1.00, the second as 0.50, and third as 0.25. As a last step we used the re-coded data as outcome variables and analyzed this data using linear regression.

We paid particular attention to gender-specific significant findings as well as the particular STEM concepts for which the students showed gain. We analyzed the correlations between career choice and factors considered important by the students in choosing a career, as well as the correlations with other factors. And finally, we performed a factor analysis to determine the underlying framework for the factors student select as important in choosing a career.

RESULTS

We have 97 matched pairs of pre- and intermediate SMK assessments and affective and career interest surveys from the 140 students presently participating in ITEAMS. Of the 97 students for whom we have matched pairs of assessments and surveys, 47 are girl and 50 are boys. Most ITEAMS cohorts are comprised of a mix of students who range in age from 5th-graders to 8th-graders. At the time they took the intermediate assessment and survey some students were in their fourth semester with ITEAMS while others were in their first, second, or third semesters. Student experiences also varied. Those students newer to ITEAMS focused primarily on learning the basic techniques for controlling and using the MicroObservatory telescopes and processing images, along with carrying out explorations related to some foundational ideas in space science.

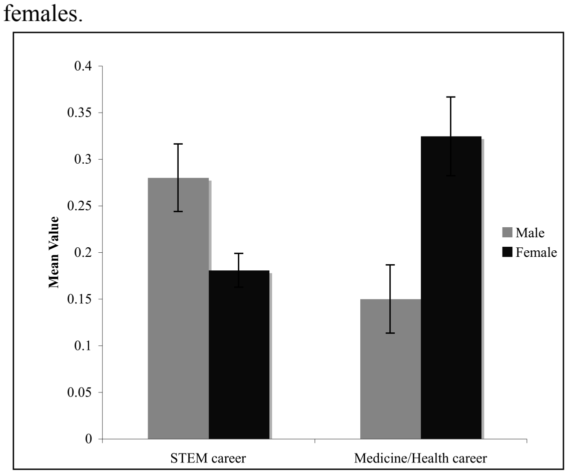
The students showed significant gain on the intermediate total test score (as compared to the pre-test), as well as on four particular items, all of which are directly addressed in the ITEAMS curriculum. From pre- to intermediate tests, the students showed an overall gain of 0.19 standards of deviation. We used a paired-samples t-test to determine significant gain when carrying out the item analysis. The students showed significant gain on four items from pre-test to intermediate test. These included: a) Boston's location on Earth relative to other places based on a time differential; b) the similarities between telescopes and binoculars; c) the shape of the Earth's orbit; and d) the length of time it takes for the Moon to fully orbit the Earth one time. The topics are all part of the ITEAMS curriculum and additional activities linked to the use of the MicroObservatory robotic telescopes. It is encouraging to see such significant gains from the pre- to intermediate tests. While the four items noted above may at first seem trivial, we find in all our testing they are neither easy nor intuitive, especially when students are tested with our DDMC items including the misconception distractors.



Graph 1: Mean Scores by Item for Pre- and Intermediate SMK Assessments.

Although the content assessment showed overall gain, there were no significant findings for gender, race/ethnicity or age. This suggests that the ITEAMS curriculum is effective for all students, regardless of their demographic background. We are encouraged by these preliminary data giving evidence ITEAMS can effectively contribute to the foundational STEM knowledge of students free of gender, race, or school bias.

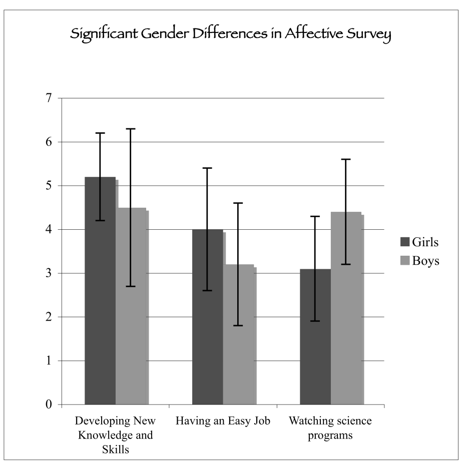
The affective assessment revealed several significant gender differences. Career choice is significantly linked to gender. Choosing a STEM career is significantly linked to males, while the choice of medicine and health careers is significantly linked to females.



Graph 2: Mean Value Representing, by Gender, the Mean from 0 to 1 for Choosing a STEM Career or Medicine/Health Career.

The option of choosing "Other Career" (including law, business and English language arts specialist) was not significant for gender. We believe that there may be at least three reasons for these results. The first could be a stereotype bias in career choice. That is, students may view the medicine and health fields as those in which they are able to work with people, caring for them and helping them. On the other hand, students may see STEM careers as more solitary and, although they may believe there is a helping component to STEM, it is far less visible than in clinical fields. Students more concerned with helping and caring for others, stereotypically females, will gravitate toward those career choices that, to their knowledge, incorporate those factors. Secondly, the arts and media portray many positive examples of careers in medicine and health, popularizing, for example, emergency medical careers. Apart from forensics, there are fewer popular examples of STEM-related careers highlighted by the media. Moreover, television and the media portray those in health and medicine careers as focused on preserving life, while forensic scientists look for causes of death, perhaps affecting girls and boys differently. And thirdly, it may be that girls associate STEM careers as requiring a time commitment preventing them from spending adequate time with their friends and family.

We carried out another ANOVA analysis focused on gender to see if interest or career factors differed for males and females. In terms of interest, boys expressed greater interest in watching science programs (and apparently do so with greater frequency than the girls). Girls, on the other hand, indicated that there were two factors in choosing a career that were significantly more important to them than to boys; developing new knowledge and skills, and having an easy job. The remaining questions on the affective survey showed no significant difference for gender.



Graph 3: ANOVA Results on Gender in the Affective Survey, with a Mean from 1 to 6 on a Likert Scale of Importance (First 2 Sets) and Frequency (Last Set).

We believe that these results may possibly be due to another effect of stereotype bias. Historically students believe that STEM subjects are more difficult than those in the arts and humanities. Girls taking this survey indicated they want to learn and succeed in school, shown by their positive responses to "Developing New Knowledge and Skills." In juxtaposition is their positive response to "Having an Easy Job." We surmise that perhaps by grades five and six girls have already perceived or experienced situations where women have had to balance family and childcare with that of a career, making a less taxing or time-consuming career a better option. It may also be conceivable that the stereotype of boys succeeding at math and science (and girls in the arts and humanities) has come into play.

CONCLUSIONS

We find that our preliminary data from ITEAMS show that an OST STEM program can promote SMK gain in all students, regardless of gender, race, ethnicity or socioeconomic status. These results suggest that a targeted intervention can have a significant effect on the gender and racial gaps so prevalent in our schools. The flexibility of the ITEAMS, as an OST program, allows students to learn at their own pace and develop mastery over time with some critical foundational space-science concepts. It also provides an entrée into the use of a unique, robotic instrument (the MicorObservatory telescope) to acquire and process research-quality data. The adaptability of the program provides for students of different ages, ability, learning styles the latitude for learning that can be impaired by the pressure of high-stakes testing.

We believe the gender differentials associated with the affective survey can add to the conversation of how science education researchers look at the gender gap. We find that girls are intellectually equal with the boys, and equally capable of learning the material and demonstrating mastery in STEM. The gender gap, at least as we find it in ITEAMS, lies not in capability, but rather in social constructs for girls and boys, and what they early on expect to do later in life, and possibly how they perceive their adult responsibilities will affect their careers. We believe that one way for girls to re-imagine career choices to include STEM is to describe how all vocations have positive and negative features, and how past policies inhibiting women from pursuing STEM careers are now changing. These shifting policies now make it more possible for either parent to stay at home with children or to care for elderly family members.

Boy's propensity for STEM and girls for medical and health fields is well documented in the literature. We show that these career decisions can often be made *before* upper middle school. These results suggest that intervention is necessary at an earlier age – 4^{th} though 6^{th} grade – if educators and policy makers hope to inspire girls and underserved populations to persist in STEM and in time, choose a STEM career.

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