

Investigating the Impact of an Outreach Activity on High School Students' Attitude towards STEM Disciplines

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Introduction

Science, technology, engineering, and mathematics (STEM) education is a growing interest in the United States. A recent five-year strategic plan published by the National Science Technology Council's Committee on STEM Education clearly outlines STEM education as a national priority, defining STEM jobs as "the jobs of the future" ¹. The report emphasizes the United States' need to invest in the engagement of teachers, students, and the public in STEM fields.

Early career interests of students are a significant factor in and indicator of their persistence in their chosen fields, and in general, young students in the United States are not fully aware of their STEM career options ². Clear differences in persistence within STEM fields vary by gender, parental income, first generation college student status, and ethnicity, with the largest factor being ethnicity ³. Additionally, STEM college major persistence is affected by factors such as high school performance in math and science, placement exams in STEM, desire to obtain a Ph.D., and a positive self-efficacy about STEM fields ³. While it is difficult to quantify student engagement, interest, and self-efficacy in STEM fields, these efforts are critical to understanding how individuals persist in or leave from the STEM discipline ².

Self-efficacy refers to perceived beliefs concerning one's capabilities to attain designated levels of performance ⁴. When students perceive satisfactory goal progress, they feel capable of improving their skills. In addition, high self-efficacy leads students to set new challenging goals for themselves ⁵. Recently, a survey of 7th grade students showed that self-efficacy affected initial data gathering behaviors, but after being exposed to a scientific-inquiry based curriculum program, the students' initial efficacy did not correlate to their scientific behavior ⁶. The conclusion drawn from this program's results was that embedding science inquiry curricula in novel platforms might act as a catalyst for change in students' self-efficacy and learning process ⁶. Self-efficacy is also positively related to outcomes in students studying in and pursuing careers in non-traditional fields ^{2, 7, 8}. For example, self-efficacy has been qualitatively shown to be related to women students' plans to persist in predominantly male-dominated fields ^{7, 9}. This trend exists for other underrepresented groups as well ⁷.

Interpretation of a student's own performance in mastery experiences shapes his/her self-efficacy in those subjects. Outcomes perceived as positive tend to raise students' confidence in their corresponding abilities and therefore strengthen efficacy beliefs^{4,9}. In addition, those that have no experience are influenced by their perception of outcomes of others that they relate to, giving insight as to why under-represented groups have lower confidence in corresponding fields^{4,9}. Self-efficacy is significantly related to academic performance¹⁰, and in particular, in STEM subjects^{11, 12}. Extra-curricular programs that expose students to STEM subjects have qualitatively shown improved student ability and confidence¹³.

Outreach events with K-12 students promoting STEM fields are abundant in a variety of forms ¹⁴. Level-appropriate outreach activities have been shown to be beneficial for all levels of

students, and tend to encourage STEM related careers ¹⁵. Outreach activities have a significantly positive impact on student perception of STEM fields and are effective to boost awareness of STEM fields ¹⁶. The purpose of outreach events in general is to spark interest and increase knowledge of the participating students. While outreach activities have qualitatively shown achievement these goals, few studies have quantitatively shown the effectiveness of such activities ¹⁷.

This paper focuses on two major research questions related to one such outreach activity: 1) What are the primary factors that impact students' attitudes toward STEM disciplines?; and 2) To what degree does the outreach activity impact students' perspectives on STEM disciplines? The preliminary results presented here address the methods used to assess the outreach activity and the effectiveness of the activity related to the research questions.

Outreach activity at SDSM&T

The specific outreach activity that will be considered here is a workshop developed by the authors that is centered on submarines and submersibles. The workshop is module-based and combines interactive lectures with hands-on activities to reinforce the concepts that are presented. The first module (Module 1) provides an overview of submarines and submersibles. Then, the following four modules go into specific STEM related topics: buoyancy and control (Module 2), environmental aspects surrounding life onboard a submarine (Module 3), pressure and structural strength (Module 4), and product development (Module 5). Finally, the last module (Module 6) involves a design competition where students form teams that design and build a tethered remotely operated submersible. These teams then compete against each other with their submersible in a several timed skills challenge (see Fig. 1). This workshop has been given to a total of eight "cohorts" in the South Dakota Gaining Early Awareness and Readiness for Undergraduates (GEARUP) program, four in the summer of 2013 and four in the summer of 2014. The GEARUP program is hosted annually on the South Dakota School of Mines and Technology campus and aims to increase the number of American Indian students that achieve success in higher education through a rigorous, pre-college enrichment program. The workshop was also given to participants in the 2013 summer science camp at the United Tribes Technical College in Bismarck, SD, and to four inmates at the Western SD Juvenile Services Center in Rapid City, SD in the fall of 2013. The interested reader can find detailed information about the content and implementation of the workshop in reference ¹⁸. It is important to point out that the data that will be discussed in the remaining sections of the paper was collected during the last offering of the workshop in the SD GEARUP program.



Figure 1. Team of students trying to complete one of the tasks (picking up an object form the bottom of the water tank and bringing it to the surface) of the design competition.

Metric development

There is a need for specific metrics to measure the impact of outreach activities on high school students' attitudes toward STEM disciplines. Meta-analysis of the literature on students' transition from secondary to post-secondary education reveals the following measures as the primary factors that impact students' perspectives of STEM disciplines ^{8-9, 20-24}.

Self-efficacy: The belief that one can persist in STEM disciplines, overcome obstacles, stress and failures, and achieve competencies to fulfill the requirements of a STEM curriculum. Studies showed that self-efficacy is significantly correlated with students' tenacity, persistence, and achievement ^{9, 19}. It determines students' confidence and use of cognitive strategies in learning ²⁰.

STEM expectations: The expectations one has about the outcomes in STEM disciplines including connections and interactions among STEM subjects, professional skills, and career options. Positive expectations contribute to smooth transitions to new environments and a healthy level of psychological stress. They also help individuals to avoid passive attitudes toward challenges over time ^{8, 21}.

Intrinsic motivation: The inherent quality of an individual that leads to persistence in a task or event ²². It includes enthusiastic involvement in tasks, desire to

experience adventure and novelty, striving for excellence in one's work, trying to understand and improve existing things, and goal direction ^{23, 24}. With intrinsic motivation, an individual can identify the value of a task and tends to try various strategies to persist in an event and achieve the goals.

Extrinsic motivation: The external factors that keep an individual in an event ^{22, 23}. An extrinsically motivated person is willing to work on a task for extrinsic rewards, grades, and praise. Extrinsic motivation can coexist with intrinsic motivation and be experienced by an individual simultaneously.

Group identification: In this study, it refers to students perceived similarities/differences with other people around him/her in specific contexts. Group identification promotes or inhibits students' capability in dealing with stress and collaborating with peers on problem solving. When students are in their comfort zones, they attempt to have more interaction with peers and/or mentors, and experience less depression, anxiety, and overall level of psychological distress.

The instrument designed in this pilot study consists of 23 items with 4-6 items per subscale. To control acquiescence and minimize non-substantive responding, reverse coded items were designed for three subscales. One male M.S. and one female Ph.D. students were involved in reviewing the items. The items were adjusted according to the students' feedback before being implemented in this pilot study. Table 1 provides a sample item for each subscale.

Subscale	Sample Item
STEM Self-Efficacy	I can do well in hands-on activities.
STEM Expectations	Math is important for achieving my future learning goals.
Intrinsic Motivation	Science/engineering projects are interesting.
Extrinsic Motivation	I will be able to use what I learn in the program to solve
	problems in daily life.
Group Identification	I have a lot in common with other students in the program.

Table 1. Sample Items from the instrument used for the assessment

Data collection and analyses

Data were collected from the high school students participating in the 2014 summer STEM outreach activity mentioned earlier by using a background questionnaire and the instrument. A total of 35 high school students were involved in this pilot study for assessing the impact of this outreach on students' attitudes towards STEM. The data collected by using the instrument were coded into the five categories described above. Descriptive analyses and statistical comparisons were employed in data analyses.

Results

The following paragraphs present the assessment results of the outreach activity corresponding to the pilot study.

Students' background: The majority of the students were American Indian students (74%) and female students accounted for 77% of the total number of students. As reported by the students, a total of 24 (69%) students' parents/guardians had at least some college coursework and 31% of them held Bachelor's degrees or higher. As can be seen in Figure 2, initially 60% of the students had the intention to enroll in a 2-year or 4-year college after high school and the number increased by 17% after the STEM outreach activity. Figure 3 presents the students' motivation for participating in the STEM outreach activity. As shown in Figure 3, 80% of the students participated in the workshop with specific academic purposes such as preparing for college and gaining a better understanding of mathematics, science, and engineering.



Figure 2. Student Academic Plan After High School



Figure 3. Top Motivation to Participate in the STEM Outreach Activity

Instrument on students' STEM attitudes: Besides the demographic background questionnaire, each student responded to A-STEM, a 6-point Likert scale assessing students' attitudes toward STEM disciplines. For each student, 23 data points were collected on STEM self-efficacy, expectations of STEM disciplines, intrinsic motivation, extrinsic motivation, and group identification. While the pilot study involved a small population, the results provide important

information about the impact of the outreach activity on the participants' attitudes towards STEM disciplines. In addition, they demonstrate the usefulness of the proposed tool for assessing STEM outreach activities for high school students. Table 2 illustrates the reliability of the subscale questions by using Cronbach's alpha. The latter reflects the internal consistency of an instrument, that is, whether the items in one subscale are closely related ²⁵.

Subscale	Cronbach's
	Alpha
STEM Self-Efficacy	.72
STEM Expectations	.80
Intrinsic Motivation	.70
Extrinsic Motivation	.77
Group Identification	.68

Changes in high school students' attitudes after the STEM outreach activity: The preliminary results indicated that the workshop had a moderate impact on students' engineering self-efficacy and motivation (6-point scale). As shown in Fig. 4, students had significantly higher perceptions after the outreach than those before in terms of engineering self-efficacy ($t_{34} = 2.72$, p < .05; Cohen's d = .33), intrinsic motivation ($t_{34} = 2.10$, p < .05; Cohen's d = .45), group identification ($t_{34} = 2.64$, p < .05; Cohen's d = .47), and overall attitude towards STEM disciplines ($t_{34} = 2.36$, p < .05; Cohen's d = .37). Furthermore, the number of students who planned to enroll in 4-year colleges increased by 17% at the end of the outreach.



Figure 4. Comparison of students' engineering self-efficacy and motivation

We found that the STEM outreach activity in this pilot study had a larger effect on students who wanted to pursue higher education in a 4-year college after high school in terms of intrinsic motivation. The average perceived intrinsic motivation of students who planned to apply to 4-year colleges after high school was similar to that of the students who did not before the outreach activity ($t_{33} = .131$, p > .05). However, a statistically significant difference was identified after

the outreach activity ($t_{33} = 2.95$, p < .05). Results indicate that students with academic goals of attending a 4-year college gained higher intrinsic motivation than others from the outreach activity ($M_{4-yr ed} = 4.66$, $SD_{4-yr ed} = .59$; $M_{others} = 4.05$, $SD_{others} = .44$). We also found that students who thought the content of the workshop was easy or very easy had higher self-efficacy than others in the post-survey ($M_{easy} = 5.00$, $SD_{easy} = .82$; $M_{others} = 4.19$, $SD_{others} = .84$; $t_{30} = 2.28$, p < .05).

Students' perspectives of the workshop modules: In general, the participants had high perceptions of the workshop, particularly the modules dealing with the topics of Buoyancy and Control (Module 2) (M = 3.60, SD = .74, 6-point scale) and Introduction to Product Development (Module 5) (M = 3.74, SD = .70), and the module corresponding to the Design Challenge (Module 6) (M = 4.34, SD = .87). On average, the students thought they learned the most from Module 2, while Module 6 was considered the most fun. More than 93% of the students believed that they learned some or many new topics from the workshop, such as buoyancy and control, designing a small tethered remotely operated vehicle (ROV), and pressure. Over 70% of the students perceived the hands-on activities as interesting or very interesting.

Discussions and future study

This paper presented the preliminary results for the impact of a submarine-based outreach activity on high school students' attitudes toward STEM disciplines. Self-efficacy, STEM expectations, intrinsic/extrinsic motivation, and group identification were assessed using the instrument designed in this pilot study. Significant increments were identified in self-efficacy, intrinsic motivation, and group identification after the outreach activity. The results suggested moderate effect of the outreach activity on high school students' attitudes toward STEM disciplines.

The data collected in the pilot study provided valuable information on the instrument and its application in the assessment of STEM outreach. For example, data show that all subscales have Cronbach's alphas above 0.70, except group identification (Cronbach's alpha = .68). There are two potential reasons. First, the subscale of group identification consists of only 4 items, while Cronbach's alpha increases with the number of items in the scale ²⁵. Second, a small sample size can also result in low alpha levels ²⁶. The smaller the sample size, the larger deviation each individual's responses can cause. A large study should be conducted with a sample size of over 1,000 high school students to further test the dimensionality of the scale using exploratory factor analysis. The pilot study revealed that an instrument to gage attitudes toward STEM disciplines could be successfully used to identify students' needs, expectations, intention, and psychological changes about STEM disciplines.

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