California State University, Bakersfield Fab Lab: ‘Making’ a Difference in Middle School Students’ STEM Attitudes

Andrea L. Medina

Andrea L. Medina, California State University
Bakersfield, CA, USA
amedina4@csub.edu

Abstract

The Fab Lab at California State University, Bakersfield provided a 1-week, half-day summer program for local area middle school students. The purpose of this study was to examine the effect this summer program had on their attitudes towards science, technology, engineering and mathematics (STEM). The theoretical framework used for this study was based on Bandura’s (1977) self-efficacy theory. Self-efficacy, or one’s belief in his or her ability to perform behaviors necessary to produce specific achievements, increases as a result of the self-guided learning. Results of the paired t-tests show a marked difference between male and female 2016 participants (n= 49) and 2017 participants (n=31). Of the 2016 participants, significance was found on overall attitudes within the engineering and technology subset (one area), male attitudes within the math, science, and engineering and technology subset (five areas), and female attitudes within the math subset (one area). The results of the 2017 program also show statistical significance in the engineering and technology subset overall, one area in the math subset for males, and three areas of science for females.

Keywords

STEM attitudes, self-efficacy, middle school, Fab Lab

1 Introduction

In 2009, President Barack Obama began the “Educate to Innovate” campaign to close the achievement gap in education and increase the STEM (Science, Technology, Engineering, and Mathematics) workforce in the United States. President Obama identified three national priorities for STEM education:

> increasing STEM literacy so all students can think critically in science, math, engineering and technology; improving the quality of math and science teaching so American students are no longer outperformed by those in other nations; and expanding STEM education and career opportunities for underrepresented groups, including women and minorities. (White House, 2009, para.7)

With a high demand for a skilled STEM workforce (Bureau of Labor Statistics, 2015), expectations have been placed upon education institutions to close the achievement gap and increase the number of qualified individuals who are ready to enter the STEM field workforce.

1.1 Literature Review

With a national call for increased STEM literacy and a robust workforce, it is important to determine what experiences inspire our youth to pursue STEM in the first place. Many factors can contribute to a student’s interest in pursuing STEM. Researchers assert that community-based programs that create STEM awareness and provide encounters for children should be strongly encouraged (Seymour, Hunter,

DOI: 10.5281/zenodo.1344440

Laursen, DeAntoni, 2004; VanMeter-Adams, Frankenfeld, Bases, Espina, & Liotta 2014). In evaluating the single most influential experience that kindled interest in STEM, more students reported that extracurricular experiences, like a visit to a museum, TV show, or an encounter with nature, and not a classroom experience, was the most influential factor in choosing to pursue STEM (VanMeter-Adams et al., 2014).

As youth embark on the middle school years, there is a general assumption that interest in STEM diminishes (Maltese and Tai, 2011; Valenti, Masnick, Cox & Osman, 2016). The development of perception of the STEM field can either restrict or encourage career aspirations (Shoffner, Newsome, Barrio Minton, & Morris, 2015). Outcome expectations, or what a person believes will happen if s/he pursues an interest or goal, are good predictors of future career choice. During these formative years, students start making decisions based on their learning experiences, which form self-efficacy beliefs and outcome expectations. Bandura's (1977) self-efficacy theory refers to one's belief in his or her ability to perform behaviors necessary to produce specific achievements. Specific examples of these beliefs can include: "If I do well in science, then I will be better prepared to go to college" [or] "If I do well in math, then my parents will be pleased." (Shoffner et al., 2015, p. 104). Middle school students who score high on outcome expectations think that doing well in math or science will mean success and approval in the future, which increases the likelihood in the pursuit and persistence in STEM (Shoffner et al., 2015). According to Lichtenberger and George-Jackson (2013) the knowledge of potential career earnings positively increased the likelihood of interest and persistence in STEM.

In addition to the national call to action to increase STEM literacy, there is particular interest for more women to enter the STEM disciplines. There are strong links between self-confidence and persistence in STEM and with regard to females in particular, self-confidence and self-efficacy play a major role in persistence (Litzler, Samuelson, & Lorah, 2014). College level female engineering students will often cite a lack of self-confidence as their reason for abandoning their STEM major (Litzler et al., 2014). Through performance accomplishments, or "mastery experiences" (Litzler et al., 2014, p. 816), self-confidence and self-efficacy beliefs are increased. Social persuasion through observation, (e.g. when a student observes someone else accomplishing a task and believes s/he is capable of the same accomplishment), verbal feedback from faculty, or working in teams with a successful outcome, are most notable in increasing women's beliefs in themselves (Litzler et al., 2014).

Although successful preparation and knowledge building are important components that increase self-confidence and self-efficacy for persistence, exposure to authentic STEM experiences are also critical in attracting students into STEM in the first place. High impact practices like project-based learning and the engineering design process are some of the strategies used to offer real world experiences and application of majors to give insight into possible career paths, which is shown to increase persistence (Garcia-Otero & Sheybani, 2012). Project-based learning may be more effective in sustaining the interest of physical science majors as it emphasizes the process of designing and not the actual product (Blikstein, 2014). Open-ended, hands-on, design and engineering projects are becoming more prevalent in education as we adopt the common core state standards and 21st century skills. Twenty-first century skills like critical thinking, complex communication, problem solving, and self-management skills are being incorporated into the educational goals of project-based learning (Unfried, Faber, Stanhope & Wiebe, 2015). The project-based learning method focuses not only on student skills like asking questions, formulating, and solving problems, but also developing solutions, collecting and analyzing data, using peer assessment, and developing results (Karaçalli & Korur, 2014). Students are given a real-life problem within a natural setting and they have the opportunity to design their own product to solve the problem. Results of project-based learning show an increase in academic achievement and retention of knowledge (Karaçalli & Korur, 2014). Student interest, attitudes, and desire to engage in science also increased at the end of a project-based process.

The Maker Movement is a relatively new strategy that emphasizes creative and improvisational problem solving, or informal learning, much like project-based learning (Bevan, Gutwill, Petrich, & Wilkenson, 2015). Enthusiasm for the potential of "new technologies and old forms of communication to transform the educational landscape" is growing (Halverson & Sheridan, 2014, p. 495). The Maker Movement has spawned such innovations as digital fabrication labs, also known as Fab Labs (Halverson & Sheridan, 2014). The very foundation of the Fab Lab came from the Maker Movement and focuses on making, or tinkering, as an educational inquiry- based practice (Halverson & Sheridan, 2014). Fab Labs create space where students can engage in project-based learning such as developing a prototype of something that can solve a real life problem (Halverson & Sheridan, 2014) through the use of technology and equipment that has historical been inaccessible to the general public.

1.2 Problem

Seen as a promising informal learning strategy, the concept of tinkering or making is struggling to gain legitimacy because it is difficult to assess the learning that is taking place. Learning outcomes are necessary to establish the effectiveness of tinkering in the Fab Lab in order to expand the Maker Movement into the education system. It has already been noted that students, with females in particular, are more likely to pursue STEM degrees when there is a high level of self-efficacy in math and/or science (Shoffner et al., 2015). It has also been stated that students are likely to persist when they have a high outcome expectancy, or the likelihood of earning a certain goal (Shoffner et al., 2015). In order to legitimize the Maker Movement as a valuable high impact practice in the education system, connections need to be made to establish persistence in STEM strategies.

2 Purpose of the Study

Due to its recent emergence, little research on the effectiveness of the Fab Lab has been published. With the growing number of Fab Labs worldwide in the Fab Network, anecdotal information on the societal impact is plentiful, however there is a lack of concrete data to legitimize the Network. The purpose of this quantitative research study was to establish the potential effectiveness of the Fab Lab as a high impact practice to engage middle school students in project-based learning activities that involved tinkering in the Lab. Using the Student Attitudes Toward Science, Technology, Engineering, and Math (S-STEM) pre and post survey, this study looked to establish a connection between student self-efficacy in STEM by comparing the before and after project-based learning activity attitudes in the Fab Lab.

The research questions addressed were:

1. What are the effects on middle school attitudes towards STEM after a 1-week summer experience in the Fab Lab?

2. What are the differences between male and female middle school student attitudes towards STEM after a 1-week summer experience in the Fab Lab?

3 Methods

3.1 Program Design

The summer program was structured as a four-day, 3.5 hours each day, no-cost summer program focusing on project-based learning activities with the intent to expose students to creative problem solving and engage them in an early engineering experience. The activities were as follows:

- Day 1- participants were given the pre-survey and then the rest of the time was spent learning how to use the vinyl cutter and complementary computer software, Silhouette Studio (Version 3.8.88ss). Participants were given the freedom to design and make any stickers they wanted during the allotted timeframe.
- Day 2- laser cutter with Inkscape software (Version 0.91pre2) was introduced. Participants were encouraged to design and make whatever they wanted using the laser cutter. A non-specific design challenge was also given to participants with instructions to use any of the equipment available for the duration of the program.
- Day 3- participants learned 3D scanning with Xbox 360 Kinect® scanner and Skanect software (Version unknown) followed by 3D printing with Cura software (Version 15.04.2). Participants

learned to scan one another's upper body for printing. While the 3D prints of themselves were being made, participants engaged in moulding and casting with Alja-safe and plaster.

- Day 4- Shopbot with V-Carve software (Shopbot Edition Version 8.505) was introduced and while the Shopbot was in operation cutting out all of their names, participants were encouraged to revisit any activity with the laser or vinyl cutters. Staff members subjectively judged the design challenge entries and trophies were awarded to the most popular design. At the end of the session, the post-survey was deployed.

3.2 Participants

Participants in this study and sample size were approximately 120 sixth, seventh, and eighth grade students that applied for the summer program. The application process was a single-page form requesting basic information from the student including address, grade, gender, and a request for a two to three sentence explanation as to why the student was interested in participating in the summer program. Participants were randomly selected by lottery after being separated into male and female applicant piles to ensure equal representation by both genders. Ethnicity was not requested by the researcher. Because this was an application-based selection process, participants were a convenience sample each year. As indicated in Table 1, 80 students were selected for the 2016 program but only 49 participants had matched pre and post surveys (32 males, 17 females). In 2017, 40 students were selected with 31 matched pre and post surveys (14 males, 17 females). Participants that did not have both pre and post surveys were considered ineligible and were removed from the data analysis.

	2016	**2017**
Selected	80	40
Eligible	49	31
Male	32	14
Female	17	17

Table 3: Participant information for summer programs.

3.3 Instrumentation

With permission from the Friday Institute for Educational Innovation (2012), the S-STEM survey was used to assess STEM self-efficacy and attitudes. This survey measures attitudes, or the combination of self-efficacy and expectancy value beliefs (Unfried et al., 2015). It can be used to understand the impact STEM programs have on attitudes and interest in STEM by helping surveyors understand students' psychological states (Unfried et al., 2015).

In order to establish validity, reliability, and fairness of the S-STEM survey, Unfried et al. (2015) "conducted exploratory factor analysis (EFA) to assess construct validity and collected content validity evidence through subject matter experts (SMEs)" (p. 625). Subject Matter Experts (SMEs) used the following rating scale to measure each construct: essential, useful but not essential, or not necessary. Using the SME rating scale, item-level content validity ratios were computed. According to Unfried et al. (2015), internal-consistency reliability of the S-STEM survey was measured using Cronbach's alpha, establishing appropriate levels of reliability. Fairness was satisfied through the use of confirmatory factor analytic tests to measure invariance or equivalence. Based on these results, items were removed or revised resulting in a final version of the S-STEM survey (Unfried et al., 2015).

The final version consists of 52-items divided into six subsets (Unfried et al., 2015). Three subsets consist of a 5-point Likert-type response scale (strongly disagree to strongly agree), related to attitudes towards math, science, and engineering and technology (Unfried et al., 2015). One subset consists of a 5-point Likert-type response scale (strongly disagree to strongly agree) and is related to 21st-century skills (Unfried et al., 2015). One subset consists of items on a 4-point Likert-type response scale (not at all interested to very interested) on interest in STEM careers (Unfried et al., 2015). Finally, one subset consists of items on a 3-point Likert-type response scale (not very well to very well) related to expectancy.

3.4 Data Analysis

A paired samples t-test was conducted on the pre- and post- S-STEM survey results. Descriptive statistics were used in order to determine the mean and standard deviation scores, and assess normality. Cronbach's alpha was used to estimate score reliability.

Results were compared between pre and post surveys and were separated by gender to examine the differences between male and female participants.

4 Results

Results from the 2016 program, detailed in Table 2, show overall practical significance with both male and female participants in the statement: "Designing products or structures will be important in my future jobs." $t(48) = -2.725$, $p<.05$, $d = 0.413$. When examining results for males only, practical significance was found in the following statements: "I feel good about myself when I do science." $t(31) = -2.10$, $p<.05$, $d = 0.282$; "After I finish high school, I will use science often." $t(31) = -3.30$, $p<.05$, $d = 0.485$; "When I'm older, I might choose a job that uses math." $t(31) = -2.06$, $p<.05$, $d = 0.289$; "Designing products or structures will be important in my future jobs." $t(31) = -2.701$, $p<.05$, $d = 0.569$; and "I am good at building or fixing things." $t(31) = -2.509$, $p<.05$, $d = 0.370$. Practical significance was found for females in this statement: "In the future, I could do harder math problems." $t(16) = -2.46$, $p<.05$, $d = 0.684$.

Statement	Gender	*n*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*
Designing products or structures will be important in my future jobs.	Both	49	-0.388	0.996	-2.72	48	0.009
I feel good about myself when I do science.	Male	32	-0.250	0.672	-2.10	31	0.044
After I finish high school, I will use science often.	Male	32	-0.469	0.803	-3.30	31	0.002
When I'm older, I might choose a job that uses math.	Male	32	-0.281	0.772	-2.06	31	0.048
Designing products or structures will be important in my future jobs.	Male	32	-0.500	1.047	-2.70	31	0.011
I am good at building or fixing things	Male	32	-0.281	0.634	-2.50	31	0.018
In the future, I could do harder math problems.	Female	17	-0.824	1.380	-2.46	16	0.026

Table 2: 2016 S-STEM survey results

In 2017, overall significance was found for both males and females for: "I am good at building or fixing things." $t(30) = -2.108$, $p<.05$, $d = 0.310$; and "I can work well with all students, even if they are different from me." $t(30) = -2.476$, $p<.05$, $d = 0.451$. Male participants were significant with: "When I'm older, I might choose a job that uses math." $t(13) = -2.28$, $p<.05$, $d = 0.280$. With female participants, practical significance was found in the following statements: "I know I can do well in science." $t(16) = -2.40$, $p<.05$, $d = 0.484$; "Science will be important to me in my future career." $t(16) = -3.77$, $p<.05$, $d = 0.531$; "In the future, I could do harder science work." $t(15) = -3.09$, $p<.05$, $d = 0.888$; "In school and at home, I can do things well." $t(16) = -2.219$, $p<.05$, $d = 0.409$. Results are detailed in Table 3.

Statement	Gender	*n*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*
I am good at building or fixing things.	Both	31	-0.258	0.682	-2.10	30	0.043
I can work well with all students, even if they are different from me.	Both	31	-0.355	0.798	-2.47	30	0.019
When I'm older, I might choose a job that uses math.	Male	14	-0.286	0.469	-2.28	13	0.040
I know I can do well in science	Female	17	-0.353	0.606	-2.40	16	0.029
Science will be important to me in my future career.	Female	17	-0.471	0.514	-3.77	16	0.002
In the future, I could do harder science work.	Female	16	-0.563	0.727	-3.09	15	0.007
In school and at home, I can do things well.	Female	17	-0.235	0.437	-2.21	16	0.041

Table 3: 2017 S-STEM survey results

In order to confirm the results of the pre and post surveys, Cronbach's alpha was used to estimate score reliability. The 2016 pre-survey had a Cronbach's alpha score of 0.895 and the post survey Cronbach alpha = 0.906. The 2017 pre-survey had a Cronbach's alpha score of 0.822 and the post survey Cronbach alpha = 0.880. The results for all four surveys reached the conventional standards for scale reliability.

5 Discussion

In 2016, male participants displayed increased self-efficacy in five areas and females in only one area, whereas 2017 dramatically shifts to only one area for males and four areas for females. It is possible that although an equal number of male and female students were selected for each summer, female participants may have attended more regularly in 2017. With more female presence, social persuasion could have caused an increase in self-efficacy.

Survey results show promise that this type of program has the potential to become a high impact practice that can influence math and science attitudes. This exciting discovery lends credence to the potential impact of the Fab Lab as an effective informal learning environment. However, due to the nature of the Fab Lab, it may be difficult to tie learning standards to activities that may be difficult to standardize. One may assume that standardization can result in the loss of the freedom to explore in the lab, which goes against its philosophy and purpose. This is important to note as most education policy changes are tied to learning outcomes.

Even though it is difficult to tie learning outcomes to something like the Fab Lab due to its environment and the activities not being standardized, scaling is still a possibility. It is important that educators and administrators recognize and understand that it is not about the product, it is the process. As long as the process retains its organic nature and educators maintain the role of facilitator and guide, not an instructor who provides step-by-step directions, other Fab Labs and makerspaces should have similar, if not identical, results with their participants.

5.1 Limitations

One of the limitations of this study was the sample size. Of the 120 selected participants over the two years, only 80 participants were deemed eligible as having both a pre and post survey to compare; 49 for

2016 and 31 for 2017. Additional programs with more surveys may confirm results, especially in the area of gender.

Another limitation of this study was the program implementation. There was no control or comparison group and the participants were a convenience sample. Because program participants were selected based on an application, it can also be assumed that the applicant already had an interest in STEM.

It is possible that because it was the beginning of summer vacation when students are desperate for a break from school and academics, participants were not excited to be at program right away. Offering the programs later in the summer may increase positive results after kids have had the opportunity to rest and recharge.

Finally, another limitation of the program might have been the lack of a stronger connection to the math and science behind digital fabrication by staff members. It is possible that additional training on how to tie the activities back to mathematical and scientific principles may increase participant understanding of the activities and thus increase their self- efficacy in those areas.

5.2 Implications

This research study focused on the short-term results of a 1-week program in the CSUB Fab Lab. A mixed-method, longitudinal study with the participants might indicate any long-term impact the program had on their persistence in STEM. This research may add to the literature confirming that an extracurricular STEM activity, like the CSUB Fab Lab, was the most influential experience resulting in STEM persistence.

Due to the difference in results by gender, another area of study into the impact on males versus females in 2016 (five areas of significance for males; one area for females) and the reversal in 2017 (four areas of significance for females; one area for males) may help determine the kind of learning environment in which females thrive.

Another area for research would be to incorporate specific design challenges throughout the week to test participant mastery with digital fabrication, with the desired effect being increased self-efficacy. Recognizing the need for unstructured time to explore and develop skills through personally meaningful projects in the Fab Lab should be standard practice in future summer programs offered to middle school students.

In addition to incorporating design challenges, increasing the amount of time in the Lab may prove to be beneficial. Offering the program over two weeks or even implementing the program as an after-school activity, may increase positive results as participants will have the opportunity to come up with innovative solutions to problems they encounter on a daily basis. As the saying goes, "necessity is the mother of invention" (author unknown), and the Fab Lab gives access to high tech, rapid prototyping machines that can turn a vision into reality.

Though limited, the results of the summer program do provide evidence of early promise. Because additional funding has been provided for the 2018 summer, the CSUB Fab Lab plans to incorporate more design challenges that encourage participants to identify a real world problem to solve in the Fab Lab. It is anticipated that by adding another layer of critical thinking, participants will connect and engage more deeply in their learning, resulting in a commitment to pursue STEM in the future.

References

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall.

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning through STEM-rich tinkering: Findings from a jointly negotiated research project taken up in practice. *Science Education, 99*(1), 98-120.

Blikstein, P. (2014). Analyzing engineering design through the lens of computation. *Journal of Learning Analytics, 1*(2), 151-186.

Bureau of Labor Statistics. (2015). STEM crisis or STEM surplus? Yes and yes. Retrieved from https://www.bls.gov/opub/mlr/2015/article/stem-crisis-or-stem-surplus-yes-and-yes.htm

Friday Institute for Educational Innovation (2012*). Middle and high school STEM-student survey*. Raleigh, NC: Author.

Garcia-Otero, S., & Sheybani, E. O. (2012, June). *Retaining minority students in engineering: Undergraduate research in partnership with NASA*. Paper presented at the meeting of American Society for Engineering Education, San Antonio, TX.

Halverson, E. R., & Sheridan, K. (2014). The Maker Movement in education. *Harvard Educational Review, 84*(4), 495-504.

Karaçalli, S., & Korur, F. (2014). The effects of project-based learning on students' academic achievement, attitude, and retention of knowledge: The subject of "electricity in our lives". *School Science and Mathematics, 114*(5), 224-235.

Lichtenberger, E., & George-Jackson, C. (2013). Predicting high school students' interest in majoring in a STEM field: Insight into high school students' postsecondary plans. *Journal of Career and Technical Education, 28*(1), 19-38.

Litzler, E., Samuelson, C. C., & Lorah, J. A. (2014). Breaking it down: Engineering student STEM confidence at the intersection of race/ethnicity and gender. *Research in Higher Education, 55*(8), 810-832.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education, 95*(5), 877-907.

Seymour, E., Hunter, A. B., Laursen, S. L., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three- year study. *Science Education, 88*(4), 493-534.

Shoffner, M. F., Newsome, D., Barrio Minton, C. A., & Wachter Morris, C. A. (2015). A qualitative exploration of the STEM career-related outcome expectations of young adolescents. *Journal of Career Development, 42*(2), 102-116.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622-639.

Valenti, S. S., Masnick, A. M., Cox, B. D., & Osman, C. J. (2016). Adolescents' and emerging adults' implicit attitudes about STEM careers: "Science is not creative." *Science Education International, 27*(1), 40-58.

VanMeter-Adams, A., Frankenfeld, C. L., Bases, J., Espina, V., & Liotta, L. A. (2014). Students who demonstrate strong talent and interest in STEM are initially attracted to STEM through extracurricular experiences. *Life Sciences Education, 13*(4), 687-697.

White House. (2009). President Obama launches "educate to innovate" campaign for excellence in science, technology, engineering & math education. Retrieved from https://obamawhitehouse.archives.gov/the-press-office/president-obama-launches-educate-innovate-programaign-excellence-science-technology-en