

Impact of Fab Lab Tulsa on Student Self-efficacy Toward STEM Education

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Abstract

Student self-confidence is important to any attempt to increase interest and achievement in Science, Technology, Engineering, and Math (STEM) education. This study presents a longitudinal examination of Fab Lab Tulsa's impact on attitude and self-efficacy toward STEM education among middle-school aged students. Paired samples t-test showed a statistically significant increase in self-efficacy among students attending four or more STEM sessions. Moreover, self-efficacy had a significant positive association with both the impact and skill level toward STEM as reported by participating students. Similarly, student attitudes toward STEM showed a significant positive association with both impact and skill level. Results of this study suggest a positive impact of Fab Lab Tulsa educational programs on STEM among students.

Self-Efficacy.

One's perceived self-competence (self-efficacy) is paramount in the motivation to pursue and to regulate effort toward a given goal (Bandura, 1997). Furthermore, self-efficacy predicts persistence toward a goal and is paramount when facing difficulties in goal attainment (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001). Studies consistently demonstrate the association between student self-efficacy and academic achievement (Schunk, 1984; Zimmerman, 2000). Bandura and Locke (2003) reviewed nine meta-analytic studies across substantive domains (e.g., education, work) and methodological designs (experimental to correlational) concluding, "The evidence from these meta-analyses is consistent in showing that efficacy beliefs contribute significantly to the level of motivation and performance." (p. 87). In educational settings, the meta-analytic studies show students who score higher on self-efficacy demonstrate persistence in the presence of barriers, develop long-term strategies, and self-regulate their progress toward their academic goal compared to lower self-efficacious students (Bandura & Locke, 2003; Multon, Brown, & Lent, 1991). Komarraju and Nadler (2013) found students with higher self-efficacy were better able to regulate their impulses and persist in the presence of difficulty toward goal attainment.

Self-efficacy plays a central role in human agentic

perspectives in that these self-beliefs affect our capacity for adaptation and achievement both directly and indirectly (Bandura, 2001; Bandura & Locke, 2003; Schunk, 2001). Patrick, Care and Ainley (2011) found that given a vocational interest, self-efficacy predicted enrollments leading toward a specific educational pathway in a cohort of students. It follows that self-efficacy is a cornerstone for student interest and engagement in Science, Technology, Engineering, and Math (STEM). Interest in STEM is due, in part, to the growing workforce demand and an increasingly limited supply of qualified applicants (Hossain & Robinson, 2012). Nevertheless, few studies exist investigating the impact of STEM programs on student self-efficacy. MacPhee, Farro, and Canetto (2013) found self-efficacy as an important predictor of performance for underrepresented STEM majors among females, minorities, and lower social economic status college students. The goal of such pursuits is to ultimately increase the number of individuals pursuing STEM related pathways as well as STEM related careers. Enhancing attitudes and confidence among students contributes to interest, learning and persistence in STEM content (Bell, Lewenstein, Shouse, & Feder, 2009). The purpose of this study is to examine the impact of Fab Lab Tulsa on student self-efficacy toward STEM education.

Fab Lab Tulsa

The Fab Lab concept was developed at MIT by Professor Neil Gershenfeld, founder and head of the Center for Bits and Atoms, who developed course titled "How to Make Almost Anything." As part of the class, he gave students access to a fabrication laboratory containing basic cutting, milling and electronic tools. Inspired by the transformative results, Professor Gershenfeld encouraged others to open similar Fab Lab's in their own communities giving ordinary people the ability to make whatever they want. To support the international growth of the Fab Lab network, the Fab Foundation was formed in 2009. The Fab Foundation mission is, "...to provide access to the tools, the knowledge and the financial means to educate, innovate and invent using technology and digital fabrication to allow anyone to make (almost) anything, and thereby creating opportunities to improve lives an

livelihoods around the world." (fabfoundation.org).

The Hardesty Center for Fab Lab Tulsa is an IRS qualified 501 (c) (3) tax exempt, not-for-profit entity located in the Kendall-Whittier neighborhood of Tulsa, Oklahoma with a grand opening 2011 (fablabtulsa.com). Fab Lab Tulsa provides community access to advanced manufacturing and digital fabrication tools for learning skills, developing inventions, creating businesses and producing personalized products. Fab Lab Tulsa is one of over 500 MIT-chartered Fab Labs in more than 70 countries and the first in the southeastern region of the United States. The STEM education program at Fab Lab Tulsa targets three constituencies: (1) K to 12 science, math and art classes, (2) afterschool program providers, and (3) related interests groups and youth organizations. Programs at Fab Lab Tulsa can be generally defined as informal STEM education that inspires student learning through hands-on, experience-based activates that enrich and add value to school experiences. Informal STEM learning takes place both during and beyond the school day hours, in the fab lab, in the schools, at community organizations, at cultural institutions such as libraries and museums, at home with their families and even online.

The Current Study

This study had two goals. First, this study longitudinally examined the impact of Fab Lab Tulsa programs on the self-efficacy of school-aged children. The second goal of this study was to examine the correlations between self-efficacy, attitudes toward STEM, perceived impact, and skill attainment among participating students. The hypothesis of this study is that self-efficacy and attitudes toward STEM would increase from pretest to posttest. Additionally, this study hypothesized that posttest scores for self-efficacy would be positively correlated with the perceived impact, and skill among participating students.

Method

Subjects:

The time frame for the study was August 2013 to May 2014. Participants in this study were selected from a variety of local organizations and schools, including nonprofit organizations that assist with troubled youth

as well as local elementary and middle schools. At the conclusion of the survey period, 158 total matched surveys had been collected. 54% of participants were male, while 46% of respondents were female. Ages ranged from 8-15 with an average age of 11.85 years (SD = 1.74). In regards to race, the majority of respondents reported being Hispanic (33%), African American (29%) or Caucasian (20%).

Procedure

The protocol for the current study was approved by the University IRB. Recruitment, consent, and data collection took place at Fab Lab Tulsa, and was administered by Fab Lab Tulsa staff. While Fab Lab Tulsa provided programming to several hundred students during the study, only students participating in a multiple session program of four to 12 sessions were targeted for recruitment in the study. A legal representative of each student provided consent to participate in the study with students providing assent. The pre-test was administered to participating groups of students during the initial orientation and before any curriculum activities had begun. The post-test was administered after the completion of all the projects. Pretest and posttest surveys were matched and de-identified by Fab Lab Tulsa staff prior to data entry and analysis by the research team.

Pilot Test

Prior to the study, the survey instrument was pilot tested at summer camps where students participate daily for one week in a Fab Lab Tulsa education program. Results and feedback from each week was used to refine the survey instrument with multiple revisions during the 12-week period. Of particular concern was the wording of questions and statements and vocabulary used. In fact, much discussion was on the definition of "technology" and "engineering" and whether students clearly understood the terms. For example, technology is often thought of as referring to computers and communication devices, such as cellphones. But in the case of Fab lab Tulsa, technology refers to any modification of the natural works made to fulfill human needs and desires. While age appropriate scales from the literature were used, the pilot testing also included assessing an appropriate reading level. The research team and Fab Lab Tulsa staff met weekly to review results and modify the survey. No data from the pilot study was used in the subsequent analyses presented below.

Measurement

STEM Self-Efficacy (Pre: $M = 23.74$, $SD = 3.30$, $\alpha = .60$; Post: $M = 24.24$, $SD = 3.36$, $\alpha = .69$) was adapted from Meluso, Zheng, Spires, & Lester (2012), and consisted of six questions using a 5-point Likert format with scores ranging from 1=strongly disagree to 5=strongly agree. Questions assessed the level of confidence individuals had with technology and design, for example, "I am comfort-

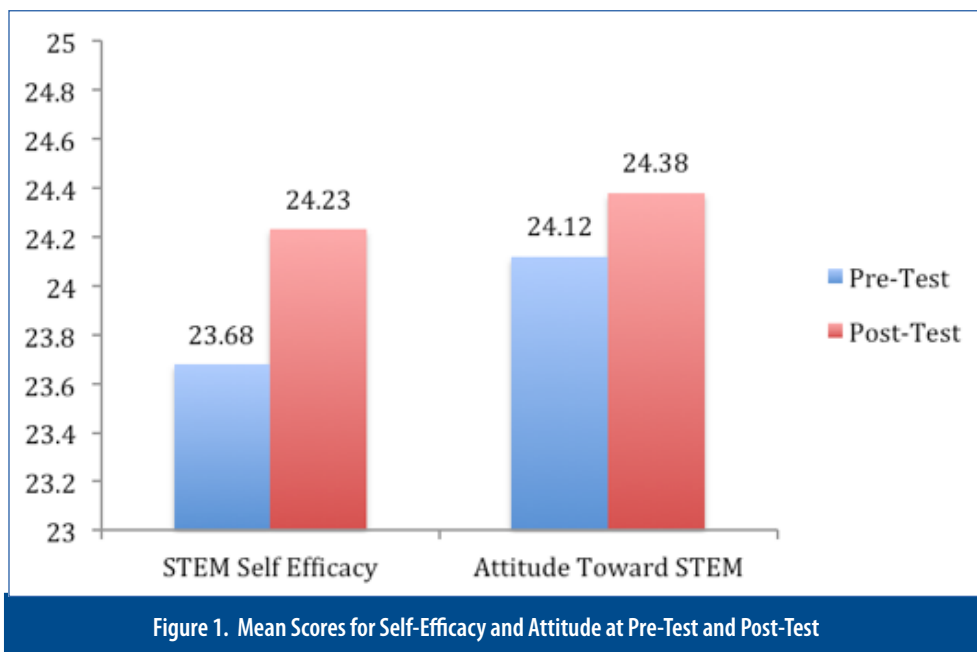


Figure 1. Mean Scores for Self-Efficacy and Attitude at Pre-Test and Post-Test

able using technology to design or make things." Higher scores are indicative of higher self-efficacy, with the range being 6-30.

Attitude Toward STEM (Pre: $M = 24.21$, $SD = 3.72$, $\alpha = .72$; Post: $M = 24.41$, $SD = 3.54$, $\alpha = .71$) was adapted from *STEM Learning in Afterschool* (2011), and used six questions with a 5-point Likert response format (1 = strongly disagree to 5 = strongly agree). Questions assessed attitudes towards technology and engineering, for example, "It is important to me to be good with technology", with higher scores indicating a more positive change in attitude. Scores could range from 6-30.

Perceived Impact ($M = 23.11$, $SD = 3.55$, $\alpha = .87$) was adapted from Melchior, Cohen, Cutter, & Leavitt (2005) and consisted of seven questions measuring ways in which Fab Lab impacted students' perceptions of engineering and technology. As an example, one question stated, "I gained a better understanding of how engineering and technology are used to solve problems in the real world." The scale used a 4-point Likert format ranging from 1=Strongly Disagree to 4=Agree, with higher scores indicating a larger impact. Scores could range from 7-28.

STEM Skills ($M = 19.25$, $SD = 2.91$, $\alpha = .68$) was adapted from Melchior, Cohen, Cutter, & Leavitt (2005) and consisted of 6 questions about the skills learned during Fab Lab ("Fab Lab helped you...Weigh different ideas and possibilities before making a decision"). Scale used a 4-point Likert format with scores ranging from 1=Not at all to 4=A lot, with a minimum and maximum score of 6 and 24, respectively. Higher scores are an indication of more skills learned.

Data Analyses

Data were analyzed using IBM's Statistical Package for the Social Sciences (SPSS version 20). Descriptive statistics (e.g., central tendency and dispersion) were

used to compute mean and standard deviation scores. Additionally, descriptive statistics were used to assess normality (e.g., kurtosis, skewness). Cronbach's alpha was used to estimate score reliability. Paired-sample t-test was computed to test the difference between pretest and posttest means for self-efficacy and attitudes toward STEM. Zero-order Pearson-Product Moment correlations were computed to assess the associations among self-efficacy, attitude toward STEM, perceived impact, and STEM skill respectively. The statistical assumptions were assessed and reasonably met prior to computing the t-test and correlation respectively.

Missing Data

Cases with missing values were eliminated from the study in listwise fashion (Peugh & Enders, 2004). Listwise deletion results in statistical analyses on variables based upon complete observations. Thus, the sample size associated with each respective analysis varied slightly.

Results

Paired Samples T-Test

A Paired Samples T-Test was used to assess the change in mean scores from pretest to posttest on the self-efficacy and attitude scales. The mean score for efficacy in the pre-test was 23.68 ($SD = 3.30$), while the post-test was 24.34 ($SD = 3.29$) respectively. This increase in self-efficacy was statistically significant from pre- to post-test [$t(144) = -.55$, $p < .05$; $\eta^2 = .04$]. The attitude mean scores for pre- and post-test were 24.12 ($SD = 3.71$) and 24.38 ($SD = 3.66$) respectively. However, changes on the attitude scale were not found to be statically significant [$t(145) = -.26$, $p > .05$; $\eta^2 = .01$].

Pearson Correlations

Bivariate correlations were run to examine the relationships between posttest scores for self-efficacy, attitude, impact, and skills. Self-efficacy and attitude scores were significantly correlated ($r = .67, p < .01$) showing higher self-efficacy scores were associated with higher positive attitude toward STEM. Change scores were also computed for the efficacy and attitude scales, and the correlation between these change scores for efficacy and attitude were significant ($r = .30, p < .01$). Thus, as individuals became more confident in their ability with technology and engineering, their attitudes then showed an associated positive change.

Self-efficacy was also significantly correlated with perceived impact ($r = .53, p < .01$) and skills ($r = .44, p < .01$). Interestingly, the efficacy change score was also significantly correlated with impact ($r = .25, p < .01$) and skills ($r = .18, p < .01$). To the extent to which individuals became more efficacious, they also reported Fab Lab having a higher impact and reported learning more skills. Attitude toward STEM scores were also correlated with almost all of the other variables. A strong positive correlation was found with attitude and both impact ($r = .64, p < .01$) and skills ($r = .56, p < .01$). A significant correlation also existed between impact and skills ($r = .72, p < .01$), suggesting that the higher the reported skills being learned were associated with higher impact Fab Lab scores.

Discussion

The goal of the current study was to assess the difference in student self-perception of self-efficacy and attitudes towards STEM related concepts after completion of a longitudinal Fab Lab project. We hypothesized the completion of a Fab Lab project spanning several sessions would result in an increase in self-efficacy and attitudes towards STEM related concepts among middle school aged students. The hypotheses were only partially supported, as self-efficacy mean scores were found to increase from pre-test to post-test, and that change was statistically significant. However, attitude mean scores, while improving, did not achieve statistical significance. Despite this, attitude scores were significantly correlated with self-efficacy scores, both pre-test and post-test, indicating a relationship does exist between increasing self-efficacy and more positive attitudes towards technology and engineering. Also of interest, was the correlations found between skills learned and impact, both of which were significantly correlated with attitudes and self-efficacy. These findings suggest that Fab Lab activities contribute toward positive attitudes and perceptions students develop towards STEM related concepts.

These findings suggest that a more hands-on approach to learning about technology and engineering may be effective in increasing self-efficacy and changing

Variable	Post-Efficacy	Post-Attitude	Efficacy Change	Attitude Change	Impact	Skills
Post-Efficacy	--					
Post-Attitude	.67**	--				
Eff. Change	.44**	.18*	--			
Att. Change	.08	.35**	.30**	--		
Impact	.53**	.64**	.25**	.23*	--	
Skills	.44**	.56**	.18*	.14	.72**	--
Mean	24.24	24.41	--	--	23.11	19.25
Std. Dev.	3.36	3.54	--	--	3.55	2.91
α	.69	.71	--	--	.87	.68

Note: * $p < .05$; ** $p < .01$.

Table 1. Zero-Order Correlation matrix

attitudes towards STEM related concepts. While a causal connection cannot be made based on this study, it is reasonable to suggest these findings are an important contribution to the growing literature on afterschool programs meant to focus on STEM. With students reporting Fab Lab to have had a big impact, including increasing their interest in math and wanting to do better in school, it is reasonable to suggest that Fab Lab is serving as a bridge between STEM concepts learned in the classroom and the real world application of these concepts.

Strengths

This study had a number of strengths that lend to it being a valuable contributor in the growing interest in ways to increase interest in STEM related concepts. The sample size was relatively large, with most analysis including at least 125 people. The sample was also quite diverse, and in some instances represented a population of children from more disadvantaged backgrounds. This large and diverse sample creates an interesting angle from which to perceive these results, suggesting that these findings are not the result of having a predetermined interest on the part of the individuals attending the Fab Lab programs. In fact, having an interest in Fab Lab, or even technology and engineering in general, was not a prerequisite for attending a Fab Lab program.

Limitations

While all participants attended Fab Lab for multiple sessions, there were some differences in the overall length of time participants spent there. For example, while some students attended Fab Lab for 12 sessions, others were

limited to only four sessions. The difference between the number of sessions attended was not analyzed for this study, as the sample size for each group was small, usually 20 or less. However, taken as a whole, the group size was such that analysis was more meaningful. The ability to differentiate between the various groups, their backgrounds, and how their responses changed over would have provided a more thorough analysis in terms of the group, but as stated previously, this was limited by the size of each group.

Implications

While the ability to generalize these findings to a larger population of youth aged 8-15 may be limited, the results do give reason to believe in the effectiveness of a hands-on approach to STEM education, particularly in regard to increasing self-efficacy and changing attitudes towards technology and engineering. Future research could continue to focus on the relationship between self-efficacy and attitudes towards STEM, as well as the role of extracurricular activities in the development of these two variables. While this project lacked the ability to make causal explanations, future studies may attempt to use a randomized control study, using a control group, which does not get to complete the program. In this way, it may be possible to examine whether the increase in self-efficacy is due to actually using the technology that is so often talked about in class, but rarely actually handled by students.

The findings presented in this study continue to support the findings of other studies examining extracurricular activities as a means to increasing interest in STEM. Past research has discussed the importance of

increasing interest while individuals are still in middle school, and in particular, using extracurricular activities as a means to increasing problem-solving skills (Hossain & Robinson, 2012). Fab Lab programs attempt to address both of these issues by utilizing hands on work with technology while allowing individuals to be creative and problem solve different ways to create their desired product.

One of the difficulties facing youth today is having access to these sorts of programs, as well as the programs having the funding to support the programs for these youth. This two-sided problem is paramount, and it has been suggested the government needs to play a larger role in collaborating with both private and philanthropic organizations (Hossain & Robinson, 2012). However, as more and more philanthropic organizations are requiring outcome-based research, which can be expensive to afterschool programs, the ability to produce these outcomes is limited.

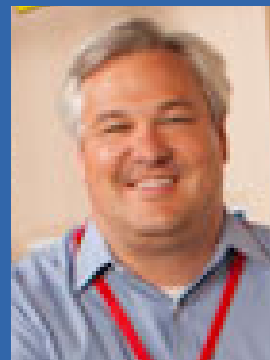
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Michelle Hardesty is the Executive Director for The Hardesty Family Foundation. Michelle came into this position with a strong background in business, as President of Hardesty Realty Corp. Michelle is currently an active Oklahoma licensed Proprietor Broker and former President of Port Trucking. Her degree in Journalism is from New York University. She is past President of Funders Roundtable, on the Regional Board for the Boy Scouts of America and the past president of the Tulsa Apartment Association. In 2009, Michelle received the Outstanding Philanthropist Award and was honored as a Woman of Distinction. She serves as Class Ambassador for Leadership Oklahoma Class XXVIII.



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