Investigating Title I School Student STEM Attitudes and Experience in an After-school Problem-based Bridge Building Project

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Abstract

Previous studies suggest a strong correlation between exposure to hands-on STEM programs and positive attitudes toward and experience with STEM subject matter amongst, middle, high school, and university students. However, there has been little research on the impact of hands-on STEM projects on Title I (socioeconomically disadvantaged) elementary students. The current study investigated the outcome of a project-based bridge design project developed for Title I elementary students using a mixed-methods research design. 36 students participated in an eight-weeks after-school project-based bridge building curriculum using K'NEX building kits. Quantitative data were collected on student attitudes towards STEM before and after the student participation using a STEM attitude survey. Qualitative data were collected via focus-group interviews at the project's conclusion. Survey results show that student attitudes toward engineering and technology had a significant increase in favorable perception after participation. However, student attitudes did not significantly change towards math or science. The focus-group interviews indicated that students had a positive experience overall and preferred hands-on activities more than research and reading. The findings have implications for the design of STEM programs guided by project-based learning (PBL) for socioeconomically disadvantaged students and communities.

Keywords: Title I schools, STEM attitudes, After-school program, Project-based learning, Bridge building

Introduction

For decades the United States government has taken steps to create equitable science, technology, engineering and mathematics (STEM) programs for Title I schools, which have high numbers or percentages of children from low-income families. Over the last 30+ years, research has documented how low socioeconomic conditions have contributed to a lack of academic success in certain schools (Sari et al., 2018). However, what the research does not suggest is that socioeconomically disadvantaged students, such as those from Title I schools, are incapable of performing at the same level given similar support (Noguera, 2011). To ignore the socioeconomic factors that exist for Title I school students would promote an inaccurate and unfair foundation of future interventions for academic improvement. One way of addressing academic success is through after school programs, which can assist poorer students in acquiring some unique experiences that would otherwise not be available (e.g., learning alongside NASA astronauts), as well as subsequently applying their newly acquired knowledge and skills from informal learning environments to formal classrooms (Yang et al., 2019; Hurst et al., 2019). This study investigated Title I elementary students' attitudes towards STEM, as well as their experience in an after-school, project-based, STEM program in order to offer insight into providing students from low-income families at Title I schools high quality STEM learning programs, and the design and development of such programs. This is timely and important since STEM education and educational equity have been accentuated in high-profile reports and documents (i.e., NGSS Lead States, 2013; National Academies of Sciences, Engineering, and Medicine, 2020) for its potential to boost national economic development. Prior research also suggests that students' attitudes toward STEM play an important role in motivating students to learn STEM subjects, and pursue STEM-related careers (Baran et al., 2019). However, students' readiness and motivation in pursuing STEM majors and careers have been decreasing due to unexpected (and paradoxical) reactions to the complex relationships between national interest in STEM, curricular practices, and pedagogical beliefs (Thomas & Watters, 2015). For example, constructivist approaches such as inquiry-based learning with heavy research components and constructing knowledge via discussions and peer interaction may increase the cognitive load on young students. Traditional didactic approaches (i.e., lecturing and rote memorization of concepts) with direct instruction would be less demanding cognitively for young students. Constructivist learning approaches, while well suited to the ill-structured problems whose solutions are not limited by disciplinary boundaries or domain knowledge (Jonassen, 2000) and are inherent in STEM fields, may function as a barrier to entry for younger students (Thomas & Watters, 2015).

To address this issue, there has been an increase in research on the effects of STEM programs on student attitudes toward STEM-related subjects and/or careers (Guzey et al., 2016; Tseng et al., 2013). This is critical since, collectively, the literature suggests that encouraging student participation in STEM projects increases their desires to embark on STEM related career paths (Baran et al., 2019; Sari et al., 2018). An important outcome that STEM subjects also have is the unique and critical role in fostering skills that not only fill employment market demands, but also the potential to help break the cycle of poverty for students from financially struggling families (Tseng et al., 2013). Moreover, real life STEM-related challenges manifest themselves in ways that are often ill-structured, which requires the cultivation of creative problem-solving abilities. In this paper we present a sub-study of a large, externally funded project focused on integrating computational thinking into STEM learning in community centers' after-school program (Yang et al., 2021). This sub-study investigated how STEM-based activities guided by PBL impacted Title I school students' attitudes towards STEM, and their experience in such activities.

Literature Review

Student attitudes toward STEM

Funding for STEM education is provided for Title I schools with the hope of ensuring that all children meet challenging academic standards (U.S. Department of Education, 2018). Despite both the national and personal economic benefits of STEM education, numerous research studies have shown that student interest and motivation toward pursuing STEM-related careers, as well as engaging in STEM learning, is declining (Drymiotou, 2021). Impoverished families are limited by regional living costs to a smaller choice in schools, likely have access to fewer advanced courses, in addition to having less experienced teachers, administrators, and skilled staff. Furthermore, poorer students lack the financial resources to engage in after-school programs or activities, buy science kits, visit museums, or take trips to places that would provide the necessary sensory-experiential foundation on which complicated STEM concepts are often built (Engle & Black, 2008; Silva et al., 2015). Sari et al. (2018) suggested that the possibility of poorer students pursuing a STEM career drops significantly when lacking these experiences in enriching or after-school activities. Nevertheless, research has found significant improvements in student attitudes toward science and engineering after participating in hands-on STEM-related projects.

Sari et al. (2018), for instance, investigated the effect of a STEM project that included different activities (e.g., reflections of light and mirrors) with 22 fifth-grade students and their attitudes toward STEM disciplines and STEM career interests. Sari's PBL-based STEM project, which included designing and constructing heat-insulated containers, alarm systems, reflective surfaces, force measurements, and an escape ramp on friction force, allowed students to practice engineering design skills. Their findings indicated that student attitudes toward science and engineering and STEM career interests significantly improved as a result of engaging in the project. Baran et al. (2019) also investigated the impact of an after-school STEM program on sixth-grade students' attitudes toward STEM disciplines and STEM-related careers. The program featured authentic learning contexts, engineering design processes, and content integration with 14 STEM modules (e.g., design of a vacuum cleaner) which embodied different scientific and engineering practices (e.g., constructing and designing solutions). The findings indicated overall that the program had a significantly positive impact on student attitudes toward STEM, and that there were also significant differences in students' science and engineering knowledge.

Numerous studies (e.g., Beier et al., 2019; Toma & Greca, 2018) have investigated the effect of STEM programs on student attitudes toward STEM across different age groups. For instance, Tseng et al. (2013) investigated university student attitudes toward STEM in a project-based learning environment where their findings suggested that students' attitudes toward STEM significantly changed after having experienced hands-on, STEM-based projects. Beier et al. (2019) examined the effect of project-based learning courses on undergraduate college engineering students. Their findings are consistent with the support for the idea that PBL STEM projects positively impact participant attitudes towards STEM. Similarly, Guzey et al. (2016) conducted a STEM study documenting a teacher's implementation of three different engineering design-based science units, and explored the impact on middle school student learning and attitudes toward STEM. Their findings suggested that engineering design activities, such as building and testing a loon-nesting platform, significantly improved student attitudes towards science and engineering.

When it comes to PBL, research regarding the application of PBL projects for elementary students is limited and results are mixed. For example, Yang et al. (2019) demonstrated an improvement in the perception of mathematics among upper elementary students who participated in an after-school STEM program via robotics. Leonard et al. (2016) described a pilot study in which robotics and game design were used to engage student with the goal of improving student attitudes toward STEM, enhance self-efficacy, and develop computational thinking skills. Their findings, however, indicated that student attitudes towards STEM did not change significantly after participating in the project. They speculated that the reason for the non-significant outcome might be the "short duration of the project or the data washout" (p. 872).

Project-based learning in STEM education

PBL is an instructional approach that provides relevant problems for students to solve using a set of design principals (e.g., creating a driving question) (Buck Institute for Education, 2019) in which the application of STEM can take place (Triana et al., 2020; Thomas, 2000). The PBL approach aligns well with the requirements for STEM professionals when it comes to solving authentic problems in the real world. It exposes students with design protocols as well as provides students ample opportunities for trial-and-error experiences which inform and refine their respective STEM knowledge. PBL encourages participants to experiment with different problem-solving approaches and reflect on their successes or failures (Hall & Miro, 2016). PBL activities create tangible and meaningful experiences for students to connect new learning to prior knowledge and past experience to address ill-defined challenges that require students to apply multidisciplinary knowledge to solve open-ended problems (Westwood, 2006).

The PBL approach and STEM learning activities complement each other well and have been investigated with various levels of students (e.g., Edmunds et al., 2017; Lou et al., 2014). Moreover, the majority of PBL guided STEM activities in these studies have occurred in K-12 classrooms. For example, Kaldi et al. (2011) designed a cross-curricular project about environmental studies based on PBL design principles which involved 70 elementary school students. Their findings revealed that the PBL activities could benefit students in their acquisition of content knowledge and collaboration skills. Lou and colleagues (2014) also integrated project-based learning in a STEM-I (Imagination) project to create a supportive and engaging learning environment in which high school students could collaborate with their peers and enhance their autonomous learning abilities. Their findings suggested that the project's activities could positively impact student imagination, learning, and collaborative learning skills.

A socioeconomic gap in the literature

The connection between student participation in STEM-related projects and their attitudes towards STEM subjects (or a potential career in STEM) in the majority of previous studies points to a positive correlation (Guzey et al., 2016; Toma & Greca, 2018). However, it is worth considering the socioeconomic background of the students who participate in these projects given that the connection between affluence and academic success has long been strongly established (Muijs, 2009). Children from low-income families and communities lag in the development of academic skills such as reading and writing compared with children from higher income families (Morgan et al., 2009). Similarly, schools in poor communities often lack resources, which negatively affect students' academic growth and development (Aikens & Barbarin, 2008). Therefore, it is possible that affluence is an underlying factor promoting the positive results regarding student attitudes toward STEM found in previous studies. 'Title I', which is often used to reflect the socioeconomic status of poorer schools and districts, was not present in the studies with PBL-based after-school STEM projects for elementary school students. Thus, further investigation on how PBL-guided STEM activities affect the perceptions of such activities, and the attitudes towards STEM-related subject areas of Title I school students are necessary.

Method

A sequential mixed-methods approach was adopted "in which qualitative and quantitative methods were employed sequentially for data analysis and interpretation" (Yang et al., 2011, p. 43). Quantitative data were collected first using an attitude toward STEM survey, and qualitative data were collected later via student focus-group interviews in order to answer the following two research questions:

1. How do Title I elementary school students' attitudes toward STEM subject areas change as a result of participating in a PBL program?
2. What are Title I school students' experiences and perceptions of PBL STEM projects?

The mixed sequential methods approach was able to incorporate the exploratory nature of the study with Title I school students with both quantitative and qualitative data (Creswell & Plano Clark, 2018) to provide a better understanding of the students' participation in the activities.

Context of study: PBL guided bridge project

The study was situated in a PBL-guided bridge building project that was centered on researching different types of bridges (e.g., cable, arch), earthquakes, and related seismic safety features via hands-on activities and problem solving. The topic of bridge building was selected because the participants live in a seismically active area of the United States. As such, designing bridges that could survive sizable ground disturbances and remain intact to support their city's infrastructure would be of personal importance, as well as an open-ended challenging problem. The project aimed to create an interactive learning environment in which students could not only learn about bridge design but also have ample opportunities to interact with peers and project facilitators to engage in authentic, engineering design activities. The project lasted for eight weeks (with two 90-minute sessions each week, totaling 16 sessions) in an after-school program offered at two community centers that serve local Title I schools.

The design of the bridge building project followed PBL design principals using an overall guiding question and different sub-questions to guide students' scientific inquiry and problem solving (Buck Institute of Education, 2019). The overall driving question was: "How can we build a bridge that is strong enough to resist earthquakes forces?". In Session 1 of the first week, the sub-question was: "What is a bridge and why do we need a bridge?". Table 1 shows the learning goals in each week and their corresponding sub-questions.

In the first four weeks of the program, the project focused on laying the foundations of bridge design with the aim of preparing students for hands-on design activities in the second half of the program. Knowledge on factors contributing to earthquake formation, potential damage, and how to measure the force of earthquakes, etc. was also introduced. For example, students learned the four different types of bridges by watching videos and using sponges and weights to simulate different bridge designs as shown in Figure 1. Computer simulation programs, such as those allowing students to experiment the forces' effect on a bridge, were also used.

In the last four weeks, the focus of the project was on hands-on bridge design and building activities. Students worked in groups of four to six using K'NEX building kits to build bridges with the guidance of teachers and subject matter experts in engineering. During the design and building processes, the students discussed, designed, and revised their prototypes of their bridge designs. In the final two weeks, students prepared for a design challenge where they competed for the best bridge design. A shake table (an earthquake simulator) was used to test the strength of the bridges built by students. The bridges that met predetermined design criteria (e.g., cost, size) and sustained the most weight would win the design challenge.

Week	Session goals/sub-questions
1	**Session 1: Understand the bridges in society**
	• What is a bridge and why do we need a bridge?
	Session 2: Understand different types of bridges and parts included
	• How do the four major types of bridges work differently?
	• When would a bridge designer want to use each type of bridge?
2	**Session 3: Understand the bridge design process and knowledge background**
	• How do I design a bridge and what needs to be considered when designing a bridge?
	• What forces affect a bridge's strength?
	Session 4: Design a bridge
	• What does a successful bridge model look like?
3	**Session 5: Understand earthquakes**
	• When building a bridge to hold weight, what ideas ensure success and why?
	• How should a bridge engineer change his/her design to meet the needs of the environment?
	• What information does a bridge engineer use to improve the construction of a bridge?
	Session 6: Understand how to design a bridge according to a plan
	• What information does a bridge engineer use to design and construct bridges?
	• What shapes and materials can resist forces acting on bridge components?
4	**Session 7: Understand how to deal with earthquake damages**
	• What is an earthquake?
	• Why does an earthquake occur?
	Session 8: Understand how to build strong bridges
	• What are the damages of an earthquake?
5	**Session 9: Design a bridge**
	• What can we do to resist an earthquake?
	• What are the considerations of designing a bridge strong enough to resist earthquakes?
	Session 10: Build a bridge
	• What are the considerations of building a bridge strong enough to resist earthquakes?
6	**Session 11 & 12: Build a bridge**
	• How do we design and build a strong bridge to counter an earthquake?
	• What are the considerations for building a strong bridge?
7	**Session 13 & 14: Build a bridge**
	• How do we design and build a strong bridge to counter an earthquake?
8	**Session 15 & 16: Determine the strongest bridge**
	• How do we design and build a strong bridge to counter an earthquake?

Table 1. Weekly Project Goals and Sub-questions

Figure 1. Designing a Beam Bridge Using Sponges and Books

Participants

Participants were recruited from two Title I elementary schools where at least 45% of students receive free or reduce lunch. Students were recruited via teachers' advertisements and in flyers posted at local community centers. Participant demographics are presented in Table 2. 25 students completed both pre- and post-surveys for the attitudinal inventory, and 16 of the 25 participants participated in the focus group interviews at the end of the project.

Data collection

Prior to collecting data, authorization to conduct the study was approved by the Institutional Review Board at the researchers' institution and the school district where the Title I schools were located. The quantitative data were collected using the "Student Attitudes toward STEM Survey-Upper Elementary School Students" (S-STEM) developed by the Friday Institute for Educational Innovation (2012). The S-STEM survey consists of 49 items covering five attitude subscales, *Science* (9 items), *Engineering and Technology* (9 items), *Math* (8 items), *21st Century Skills* (11 items), and *Interest in STEM Careers* (12 items). The items were measured on a 5-point Likert scale with 1 being *strongly disagree* and 5 being *strongly agree*. Unfried et al. (2015) established the content validity of the S-STEM survey by consulting subject matter experts

	Gender		Grade		
	Male	**Female**	**4th**	**5th**	**6th**
Spring 2017 (survey n = 13)	9 (69%)	4 (31%)	7 (54%)	0	6 (46%)
Spring 2017 (interview n = 12)	9 (75%)	3 (25%)	7 (58%)	0	5 (42%)
Fall 2017 (survey n = 12)	9 (75%)	3 (25%)	7 (58%)	4 (34%)	1 (8%)
Fall 2017 (interview n = 4)	4 (100%)	0	1 (25%)	3 (75%)	0

Table 2. Participant Background Information

Sub-scale	Application of Measurement
Math Attitudes	measuring self-efficacy related to math and expectations for future value gained from success in math
Science Attitudes	measuring self-efficacy related to science and expectations for future value gained from success in science
Engineering & Technology Attitudes	measuring self-efficacy related to engineering and technology and expectations for future value gained from

Table 3. S-STEM Survey for Three Subscales

Student Attitudes toward Mathematics, Science, Engineering and Technology

Subscales	Pre-survey		Post-survey			
	Mean	*SD*	Mean	*SD*	*t*	*p*
Math	30.83	2.725	33.75	5.545	1.860	0.090
Science	34.75	5.578	36.83	6.279	1.780	0.103
Engineering & Technology	35.00	3.075	37.08	2.778	2.380	0.036*

Note. $^{*}p < .05$, 2-tailed.

Table 4. Student Attitudes toward Mathematics, Science, Engineering and Technology

and validated the internal-consistency reliability by using confirmatory factor analysis. For this study, only the data from three subscales (*Science, Engineering and Technology, and Math*) were analyzed. Table 3 displays the summary of the three sub-scale sections in the S-STEM survey.

Student focus-group interviews were conducted at the end of the project and were videotaped. Participation criteria was based on students' availability. A list of interview questions was determined prior to the interviews and included questions like "*why did you choose to participate in this project*?", "*what do you like about this bridge project*"?, and "*how do you describe your experience in this project*?", etc. All interviews were conducted by the same researcher.

Data analysis

Survey data were analyzed in SPSS 27 after assumptions for paired-T-tests were checked and satisfied (interval data of scales, matched data points, no outlines, and appropriately normal distributed data). Student focus-group interviews were transcribed and analyzed in NVivo. The research team reviewed the transcripts and then developed several top-level nodes based on the interview questions. For example, student responses to the question, "what do you like about this bridge project" were coded under the node of "positive experiences", and responses to the question, "which part of the bridge project you don't like the most" were under the node of "negative experiences". Saldaña's (2016) "in vivo" descriptive coding techniques were employed to generate more specific sub-nodes that could be clustered under the top-level nodes in the first round of data analysis. The descriptive coding refers to the use of "a word or a short phrase from the actual language found in the qualitative data record" (Saldaña, 2016, p. 105) to code the data. For example, when asked about students' positive experiences in the project, a student answered, "*I did not dislike anything, I like it all*". Thus, when applying the "in vivo" technique to this quote, the answer was coded as "*Like it all*". Further, a descriptive coding was used to describe the topic of data. For instance, a quote describing a student's negative experiences in the project "F*or me, it wasn't just that we researched too much on earthquakes, I think we research too much. It was just too much like just being at school*" was coded as "*the reading or researching part*". A memo was kept during the coding process to ensure that coding was consistent.

Results

Title I elementary school students' attitudes toward STEM subjects

The post-survey means of students' attitudes towards STEM subjects were larger than those of the pre-survey, indicating some improvement. Table 4 shows the pre- and post-survey means for the three subscales of the S-STEM survey and the results of a paired t-test. The means of student attitudes toward all three subject areas have increased in the post-survey.

Comparing the pre-test (M = 35.00, SD = 3.075) and post-test (M = 37.08, SD = 2.778) of the students' attitudes toward *Engineering and Technology*, the analysis showed a significant difference (p=.036) in students' attitudes toward Engineering and Technology after students participated in the PBL bridge design project. However, there was no significant difference between the pre- and post-survey on attitudes towards *Science* (*p*= 0.103) or *Math* (*p*= 0.09).

Title I school students' experience and perceptions of the PBL STEM project

We performed a "word frequency" query in NVivo on interview transcripts to identify the most frequently used words (excluding certain lexical items like articles, adverbs, etc.) to help reveal students' perceptions. This is illustrated in a word cloud in Figure 2. The word "fun" was the third largest in size and appeared most frequently right after "bridge" and "building". To some extent, this reflects students' overall learning experiences in the project.

Students were first asked why they chose to participate in the project. The primary reason for student participation was wanting to learn about building a bridge and having fun with others. This sentiment was a common feeling among the majority of the students. For example:

> *I did it because I want to learn about bridges and see people that build the bridges, and have fun with my friends to do it and just doing it is fun I thought.*

To build bridges was another influential reason in students' desire to participate in the program. The activities of designing and constructing bridges demonstrated an elevated interest and revealed participants motivation to get involved in the after-school project. Table 5 shows the common reasons students stated for their participation. "In vivo" codes are provided in the left column with sample responses in the center, and the frequency of utterance on the right. The number of participants interviewed was 16. Individual participants could cite more than one rea-

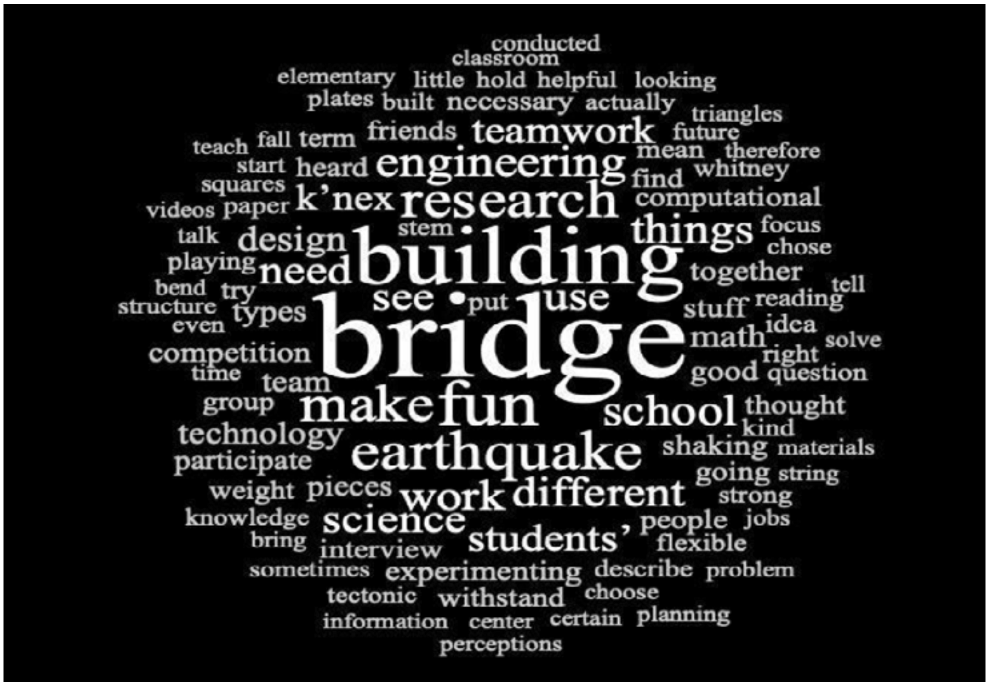

Figure 2. Focus-Group Interview Word Cloud

son in their responses.

Students' positive experiences in the project. Students were asked about what they enjoyed most in the program. A total of 16 students answered this question. Students' answers covered a wide range of topics, from the bridge building with K'NEX itself, while other students enjoyed the research, the final competition, and the design challenge in the end (see Table 6).

One student described his experiences in the project as "*I like how we were actually trying to build something that can survive the earthquake and hold two kilograms of weight.*" The above quote provides evidence that the student's engagement and seemingly positive experience could be connected to PBL's inherent mandates for contextualization of the learning experiences (Duch et al., 2001). All of the material presented during the project was centered on the goal of building a bridge that could resist the physical trauma induced by an earthquake. Table 6 presents the participants' positive experience, corresponding supporting quotes, and the percentage of participants who shared such aspect of the experience.

It seemed that a large percentage of students enjoyed the bridge design challenge at the end of the project. The purpose of the challenge was to provide an opportunity for students to show what they learned in front of an audience (students' parents and interested community members such as teachers and principals).

Students' negative experiences in the project. Another interview question asked what students disliked the most in the project, with the intention of improving the project. A total of 10 students answered this question.

Six interviewed students commented on the reading and research activities. It was consistent with the project team's observations that the reading and researching part in the first four weeks was not as engaging as the hands-on engineering design activities in the last four weeks, as one student commented that:

> *I just don't like all the time we did research because I think we did too much research on the earthquake and research on the bridges. We kept on researching the earthquakes, but I think it's not mostly about the earthquakes when building bridges. It is about learning where the shaking is going to be coming from. So, all you need to know is where the shaking is coming from and how strong it will be. But I think we did a bit too much research on earthquakes.*

However, even though the reading was not that interesting for the students, they had to go through it in order to obtain necessary knowledge on bridges and earthquakes. As it was expressed by a student, "*I learned what shape of structure [square or triangle] would make a bridge stronger in early research week . . . .*" Another student also said, *"I learned how earthquakes were formed. They are formed when two tectonic plates get stuck together and then they break off and cause earthquakes."*

Apart from the reading, two students mentioned wanting a different timing for the project because it was tiring to do anything right after a whole day of school. One student said that his group did not have the necessary materials to complete the design in a couple of ses-

Reasons	Sample Quotes	Percentage
To build bridges	I like to do all the after-school activities, like the Mars, really fun, the Silver Box, really fun. I signed up for this because all the others have been really fun. I just like building stuff. It is just Legos, K'NEX, and blocks. As long as it is a team group and building, it's really fun. I did it because I really like science, and it may be a good chance to learn something different.	50%
Like STEM	I chose it because I love science, technology, engineering, and math.	21%
Learn things	I did it because I really like science, and it may be a good chance to learn something different.	14%
Do something after school	I chose it because I wanted to do something after school.	14%
Peer influence	I started it because a couple of my friends were doing it and it sounds really cool designing a bridge and engineering.	7%
Cool to participate	I did this bridge project because I thought it would (be) a cool opportunity to do it after school.	7%

Table 5. Reasons to Participate in the PBL Bridge Building Project

Positive Experiences	Sample Quotes	Percentage
Building bridges with K'NEX	I just like playing with the K'NEX like whenever I get the K'NEX, I just start playing around with the pieces, see what you can build and experiment. I like the bridge building because we got (to) experiment. Experimenting is always fun, experimenting what will happen if you hit something with a hammer. Experimenting is fun.	81%
Competition in the end	I like the building part and the competition at the end.	25%
Like the videos played	I like it because the videos that we got to see and how they worked on what to put in the bridge, and all the types of bridges.	19%
Like it all	I didn't dislike anything, I like it all	13%

Table 6. Students' Positive Experiences in the Project

Negative experiences	Sample Quotes	Percentage
The reading/researching part	For me, it wasn't just that we researched too much on earthquakes, I think we research too much. It was just too much like just being at school. I don't know if I really like the studying part because I signed up just to build some bridges. And you know, the learning part is good, but I think we could build what they were trying to teach.	60%
Bad timing	I think it is right after school and maybe you could do it during different times of the day, not right after school.	20%
Disappointing at the end of project	I felt disappointed because our group lost the competition.	10%

Table 7. Students' Negative Experiences in the Project

sions due to the late delivery of some materials (such as weights). Another student mentioned that it was a bit disappointing at the end because his group lost the design challenge. Table 7 presents the negative aspects of students' experiences, some sample quotes, and the corresponding percentages of the students who responded. Despite some negative perceptions, the students seemed to have had fun with the project which was reflected in the word cloud (see Figure 2), as well as students' responses to the first two interview questions.

Discussion

Title I schools are associated with lower income communities, which can fall into a cyclical cross-generational poverty. STEM subjects have a uniquely high potential to break this cycle due to both the national need for skilled STEM professionals, and the high-income potential for these trades. The goal of this project was to provide socioeconomically disadvantaged students at Title I schools STEM learning opportunities and help them develop problem-solving skills while engaging in bridge building activities. The project was guided by PBL principles which enabled students to conduct hands-on engineering design and building activities, potentially influencing their perceptions of STEM. Consistent with previous literature (Guzey et al., 2016; Sari et al., 2018) on hands-on activities and PBL, we found that students' attitude towards engineering and technology has significantly improved. However, participants' attitudes toward math and science did not improve in this study.

We found that the students described engineering design activities with the K'NEX kits as "fun". The fact that most Title I school students had not had the opportunity like building a bridge using K'NEX kits might have contributed to this sentiment. In terms of the subject content, it is possible that because engineering is more hands-on in nature, students perceived it as being more fun. It is also possible that this is the result of the activities being more in line with the domain of engineering rather than math or science, thus resulting in a favorable perception of engineering and technology. Future research should clearly distinguish various subjects while investigating which one Title I school students prefer more to gain a better insight into the nature of facilitating the PBL STEM activities.

For Title I school students, who come mostly from low-income families, resources such as K'NEX kits, and tools such as the shake table, could be considered more as entertainment or a luxury than a regular staple of an educational setting. Despite students' interest in engineering design and building activities, access to these kinds of resources would normally be absent. Limited access to similar after-school PBL STEM activities for Title I school students might also be a contributing factor to the reason why participants attitudes toward E*ngineering and Technology* had significantly improved. If we want to improve student attitudes towards specific subjects, interventions or programs need to be closely associated with a specific discipline.

As reflected in student focus-group interviews, students had a "fun" experience in the PBL bridge design and building project, which was indicative of their reactions to, and perceptions of the activities. Students' positive experiences mainly arose from the preferred hands-on experience of using K'NEX building kits to build bridges, which aligned with most of the reasons for participating in the project. Other positive aspects of the project included the design challenge in the end and the videos students watched during sessions. At the same time, students expressed that the project contained too much reading and research components, which made them feel like "*just being at school"* again since research through reading and inquiry is often the hallmark of traditional classrooms. It seems students viewed that as a comparatively higher workload. This finding reflects the challenge of using PBL with elementary school students due to factors such as high cognitive demand and ability to research (Thomas & Watters, 2015). However, the presentation of the necessary background knowledge at the beginning of the project was necessary. Researchers and practitioners need to work on how to convert the "reading and research" aspect of such curriculum into age-appropriate PBL STEM activities to avoid adverse reactions. It is possible that the reading and research components could have negatively impacted student attitudes toward math and science in the post-survey.

The overall PBL approach promotes problem solving with need-to-know information based on the status of a project, whereas traditional instructional approaches present students with information without the need to figure out how to apply it to solve problems in complex situations (Thomas & Watters, 2015). Therefore, it would be helpful to make research processes more time efficient by providing such background information only if/when absolutely necessary. In simpler terms, a hybrid pedagogical approach blending both didactic and constructivist paradigms may be beneficial for young or inexperienced learners in certain contexts. It is reasonable to view Title 1 students as inexperienced since they have a more limited choice in schools, likely less access to advanced courses, in addition to being in schools with less experienced teachers (Aikens & Barbarin, 2008). For future implementations, it may be necessary to communicate the overall objective of a PBL STEM project to the students at the beginning so that they understand the need to acquire fundamental knowledge before engaging in hands-on problem-solving activities (which students here viewed as "fun"). Additionally, identifying key areas of math and science that can be implemented in a PBL project may help improve student attitudes toward math and science for a comprehensive improvement in STEM fields. In this sense, it is likely that a pre-existing favorable view of engineering (bridge design and building) contributed to students' willingness to participate in the program in the first place. Program participation may also have been related to the novelty of the project, which may have attracted some students that did not have an interest in STEM. Nevertheless, further investigation of student attitudes towards STEM is warranted with PBL STEM activities and Title I school students. Further, some students were below the reading level for their respective grade level and may have experienced some difficulty understanding and filling out the survey during data collection. The researchers and teachers had to assist in explaining the survey items to some students when they filled out the survey. Therefore, it is possible that some students did not accurately understand the questions. Lastly, the required reading and research in the project bored students to some extent (see Table 7), which might have negatively affected the students' post-survey responses.

Conclusion

This study investigated the impact of an eight-week after-school PBL bridge building program on Title I school students' attitudes toward STEM subjects and their experience in a PBL STEM project. The quantitative data showed that the students' attitudes towards engineering and technology changed significantly, which was corroborated by qualitative data where students described the activities as "fun". The findings have implications for the design and implementation of PBL STEM projects/activities for Title I school students and students from low-income families. Practitioners could expose Title I students to after-school STEM-based engineering design activities to help students improve their attitudes towards STEM, and specifically towards engineering and technology. Regarding the curriculum design, it is suggested to both reduce the amount of text-based information research and scientific inquiry, while increasing the use of multimedia for presenting the content. In terms of implementation, it is necessary to explain the underlying rationale of the learning process so that students know why they need to learn certain items before jumping into the more preferable "fun" hands-on activities. This study suggests an avenue for helping socioeconomically disadvantaged students break the cycle of poverty which often characterizes Title I schools and surrounding communities. Further, PBL guided STEM projects could help reduce the shortage of STEM talent in the national workforce and create interest in STEM fields early on for students.

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