Engineering After-School Program with Elementary Preservice Teachers and K-8 Students

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ABSTRACT

This study explores the influence of an afterschool program involving high needs elementary-aged students at community-based sites and elementary preservice teachers (EPSTs) enrolled in a final sequence of methods courses at a local university. Data collection involved surveys, interviews, and reflections with EPSTs and interviews with elementary-aged children. Results indicated a significant positive correlation between EPTSs' science perceptions and science teaching self-efficacy. A series of Wilcoxon Rank Sum tests indicate significant growth from pre to post in participating EPSTs' self-efficacy with the NGSS and the Engineering Standards within the NGSS. Interviews and reflections provided evidence that EPSTs benefited from the program by teaching in an unfamiliar setting that changed their beliefs and helped strengthen their teaching skills. Interview results for elementary-aged children revealed a hands-on, although somewhat limited, perspective of science, technology, and engineering. Perceptions of mathematics were primarily focused on computation.

Key Words: *STEM, Elementary Preservice Teachers, Elementary-aged Children (K-8), After School Program*

With many states adopting the Next Generation Science Standards (NGSS; Achieve, 2013), there has been a shift in the way science education is conceptualized for elementary classrooms. In addition to including skills and practices related to science content, more familiar to educators, the NGSS embed engineering practices, which are largely unfamiliar to elementary preservice teachers (Committee on Integrated STEM [science, technology, engineering, and mathematics] Education, 2014; Katehi, Pearson, & Feder, 2009). Embedding engineering practices within a science methods course is not only important because engineering is included in the NGSS, but because it effectively supports introducing engineering with preservice teachers (Hudson, English & Dawes, 2009).

It is imperative that preservice teachers be provided with meaningful experiences that allow them to envision how they can implement the NGSS in their future classrooms. According to Goodlad (1990), preservice teachers "judge the quality of everything encountered on the grounds of perceived practicality" (p. 225). Research supports this because when teachers have authentic teaching experiences, their self-efficacy related to teaching increases (Flores, 2015). This finding is particularly important considering the extensive body of research showing a connection between teacher beliefs and their classroom practice (Aguirre & Speer, 1999; Thompson, 1992). In order to ensure that teachers embed the NGSS as intended in their future classrooms, they need to be provided with authentic experiences using the standards as part of their teacher preparation program. This study examines an afterschool outreach program that includes the NGSS and embedded engineering practices.

Theoretical Framework

Field Experiences for Preservice Teachers

Hollins (2011) notes the integrated role of preservice teacher knowledge, practice, and perspectives when putting forward a theoretical position for practice-based preservice teacher preparation. With this approach, there is an attempt to provide insight based on previous work in the field on how to best prepare preservice teachers in the complex environment of the classroom. Authentic field experiences allow preservice teachers to learn more about the art of teaching and develop a better understanding of the learners within the classroom, which, in turn, informs their teaching philosophy. Bodur (2012) found teacher education programs can incorporate practices that positively change preservice teachers' attitudes related to teaching culturally and linguistically diverse students. One of the key components noted in interviews regarding why their attitudes changed was their experience in the field working with these diverse students (Bodur, 2012). Darling-Hammond, Hammerness, Grossman, Rust and Bransford (2005) discuss the importance of field experiences for teacher preparation programs noting that preservice teachers need to learn "about practice in practice" (p. 401).

One way to provide preservice teachers with these types of experiences is through community-based field experiences, which research has shown helps connect education theory with the practice of teaching (Coffey, 2009). Preservice teachers benefit most from participating in an immersion program, where they spend extended time in culturally diverse settings in schools and the community, which prepares them to be culturally responsive teachers (Wiggins, Follo, & Eberly, 2007). However, research also supports less intensive field experiences (Lazar, 1998). The quality and impact of these field experiences goes beyond the setting, also relying on the quality of interactions, self-reflection, and connection to classrooms. Sleeter (2008) provides a recommendation for "teacher education for equity and democracy" through three pillars: "preparation for everyday realities and complexities of schools and classrooms; [sic] content knowledge and professional theoretical knowledge that universities can provide; [sic] and dialog with communities in which schools are situated" (p. 1948). Field experiences should allow preservice teachers to see the interwoven nature of schools and their communities in order for them to be adequately prepared to enter these classroom settings as future educators. The setting of this study was an after-school engineering program, taught by preservice elementary teachers, using LEGO kits to engage K-8th graders.

After-School Engineering Program for Children

The continued underrepresentation of minority groups pursuing engineering and science calls attention to the need for opportunities that might encourage children's heightened interest and dispositions toward STEM. The National Science Foundation and National Center for Science and Engineering Statistics (2017) report that out of all bachelor's degrees awarded in science and engineering, 11.5% were awarded to individuals identifying as Hispanic, 0.5% identifying as Native American, and 8.3% identifying as Black or African American, despite representing 16.3%, 0.9%, and 12.6% of the U.S. population (Humes, Jones, & Ramirez, 2011). Educators and researchers must consider methods for changing the way students perceive and experience engineering if a greater, more diverse population of students is to be attracted to the field. Research indicates early exposure to STEM, through programs or initiatives, supports students' attitudes, beliefs, and identity related to these fields (Bybee & Fuchs, 2006; Lock, Hazari, & Potvin, 2019).

In particular, experiences with robotics are beneficial for both preservice teachers and elementary-aged students. For example, Elkin, Sullivan and Bers (2014) found the use of robotics as part of an early educator's curriculum provided the teacher with an opportunity to integrate engineering concepts and increased her confidence in using technology. Further, when preservice elementary teachers are provided with authentic opportunities to do science, such as engaging in scientific inquiry, their self-efficacy about teaching science and conceptual understanding of science increases (Avery & Meyer, 2012). These types of field experiences benefit elementary students, providing them with opportunities to develop problem-solving skills (Bers, Flannery, Kazakoff & Sullivan, 2014), supporting students learning 21st century skills (Ma, Williams, & Lai, 2016) and increasing students' attitudes toward STEM (Ching et al., 2019) – particularly for underrepresented groups (Karp & Maloney, 2013). The nature of the field experience is also important with preservice teachers who are "confronted with novel, challenging, and oftentimes, unexpected tasks" triggering changes in efficacy related to STEM (Thomson, DiFrancesca, Carrier, Lee, & Walkowiak, 2018, p. 38).

A community-based, after-school engineering program was developed and implemented with consideration to prior work on effectively supporting elementary preservice teachers' knowledge and beliefs related to engineering practices (as detailed in the NGSS) and providing underrepresented children (K-8th grade) with meaningful experiences in engineering. This study explores the effectiveness of the program and the types of experiences participating elementary-aged children had through the following research questions:

1. Do participating EPSTs' perceptions of science correlate with changes in their attitudes and beliefs about teaching science and the Next Generation Science Standards?
2. Does participation in the LEGO Project change EPSTs' attitudes and beliefs about teaching science?
3. Does participation in the LEGO Project change EPSTs' level of knowledge, understanding, and confidence toward the Next Generation Science Standards?
4. What are elementary-aged children's knowledge about and experiences with science, technology, engineering, and mathematics?

Methods

Community-based Field Experience

The community-based field experience involved a partnership between a local university, Housing Authority, and Boys and Girls Club. Both after-school program sites serve similar student populations. While these programs accept students from many of the local elementary schools, students primarily attend two schools, which are representative of the population being served at the Housing Authority and Boys and Girls Club. These schools both have high free and reduced lunch attendees and high minority and international populations as shown in Table 1.

Table 1

School Student Demographics Served by the Housing Authority and Boys and Girls Club

	Elementary School 1	Elementary School 2
Free and reduced lunch	93%	94%
African American	21%	40%
Asian	3%	4%
Hispanic	39%	27%
White	31%	18%
American Indian or Alaskan Native	0.2%	0.3%
Native Hawaiian or Other Pacific Islander	0.0%	0.7%
Two or more races	5.5%	9%

Through this partnership, EPSTs designed and taught engineering-based lessons for elementary aged children. Before EPSTs visited the field experience sites, the students participated in two training sessions on the engineering design process and the LEGO robotics (NXT) kits. The first session used the Engineering is Elementary model (www.eie.org) to learn and participate in an example lesson of the engineering design process. The second session included information on components of the NXT kits as well as challenges for creating and programming the kits. EPSTs worked in teams of three or four to design and implement two engineering-based lessons at one of the community sites. These lesson plans asked EPSTs to write a lesson objective, indicate the engineering practice as outlined in NGSS addressed in the lesson, provide a justification for how the engineering practice was meaningfully integrated in the lesson, and detail the procedures of their lesson plan (including all activities, pacing, and potential questions/prompts). One of the two lessons students implemented was for K-3rd grade students using the LEGO machine kits, and the second lesson was for 4th-8th grade students using the LEGO robotic kits. EPSTs self-selected their partners and date to teach the two lessons they designed at one of the community sites. Lesson plans were submitted to a separate project classroom site where they could be reviewed by one of the project facilitators (students' science methods and curriculum instructors). In addition to posting lesson plans so project facilitators could review and provide feedback, EPSTs had access to a STEM instructor with expertise in engineering. At the choice of EPSTs, much of the feedback provided was communicated via email rather than through meetings with instructors. Immediately after each team implemented a lesson in the field, EPSTs were required to submit a reflection. These reflections were posted so that all students could review what was occurring at each site and plan accordingly. For example, if a team presented a challenge to build a robot that could move a ball, but the participating children did not complete the challenge, the next team planning a lesson for the site could pick up where the previous team had left off. This was particularly helpful for EPSTs planning for the older group of children who worked all semester to build robots with the NXT kits; thus, lesson plans had to build on one another. The younger group of children generally experienced separate lesson plans each time, but the reflections served to avoid repetition, provide inspiration, or allow for extensions when teams planned their lessons.

The facilitators visited with both sites prior to EPSTs lesson implementation to give an overview of the program to participating elementary-aged students. This was used as a recruitment tool to interest students in participating the following weeks. To support students and EPSTs and provide a level of consistency throughout the semester, an experienced secondary preservice teacher (SPST) was present at each site during the implementation of lessons. This

SPST was responsible for bringing LEGO kits to each site and providing support to EPSTs during lesson implementation. After all the EPSTs finished implementing their lessons, the last week the project facilitator and a team of secondary preservice teachers (not included in the study) visited the community sites to implement activities highlighting different fields/careers of engineering. Additionally, the three project facilitators rotated in their visitation of the sites throughout the semester as lessons were implemented.

Participants and Procedure

Data were collected during the fall semester with 60 elementary preservice teachers' (EPST) in two sections of an elementary science methods course at a mid-south university. Pre-surveys were administered during the first week of the semester before any project activities were conducted. Post-surveys were administered during the last two of weeks of the semester after all lesson plans were implemented. Semi-structured interviews were also conducted during the last couple of weeks of the semester with three EPSTs. Interview questions focused on the preservice teachers' experiences as part of the community-based field experience including what each participant learned and how the experience influenced his or her beliefs about teaching.

Ninety-five percent of the participating group of EPSTs identified themselves as female; 100% of the participants were in their senior year of college and were between the ages of 18-25. Ninety-six percent of the participating EPSTs indicated that they were White, 2% indicated they were African American, and 2% indicated they were multicultural.

Elementary-aged children participating in the LEGO project were divided into two groups based on grade level (K-3rd grade and 4th-8th grade) at each of the two sites. Table 2 provides an overview of the K-8th grade participants by site. Students could opt to participate in the LEGO Robotics club or not on a weekly basis, so different children participated over the semester. Additionally, it is important to note that participation in the program was not dependent on whether or not the child participated in the study; therefore, the number of children who participated in the LEGO project was greater than what is reported in the Table 2. The same data collection methods were implemented at each of the sites. However, with the number of survey responses being low, only interview data will be reported in this study. Semi-structured interviews were conducted at the end of the semester.

Table 2

K-8th grade participants

Site	K-3rd Grade	4th-8th Grade	Total

Housing Authority	11	1	12
Boys and Girls Club	2	5	7
Total	13	6	19

Fifty-three percent of the elementary-aged participants (self-reported) identified themselves as female. Children's ages ranged between 5-12, with the average age of 7.3 for K-3rd grade participants and 10.2 for 4th-8th grade participants. Forty-seven percent of the participating students indicated that they were African American, 18% indicated they were White, 18% indicated they were American Indian or Alaskan Native, 12% indicated they were multicultural, and 6% indicated they were Asian. In addition, 12% indicated there were of Hispanic origin and 12% indicated that English was not the language spoken at home.

Instrumentation

To address the research questions pertaining to preservice teachers, a survey was administered using the STEM Semantics Survey (Tyler-Wood, Knezek, & Christensen, 2010), Inquiry Science Teaching Belief Instrument (Avery & Meyer, 2012), and six researcher created items. The STEM Semantics Survey had a 7-point bi-polar scale, with the following Cronbach's alpha for constructs: Science (0.90), Math (0.89), Engineering (0.89), Technology (0.88) and STEM Career (0.94). Although there is some prior validation research using the Inquiry Science Teaching Belief Instrument (ISTEBI), the limited published work with this instrument and the low reliability of the constructs (both in the prior work and in the current study) promoted the research team to examine the constructs more closely. Exploratory factor analysis (EFA) was conducted to examine the factor loadings along with other results such as eigenvalues, scree plots, and parallel analysis. This analysis led to revisions in the items included within each construct. A summary of items that were removed along with the original and revised Cronbach's alpha values for the constructs are included in Table 3. It is important to note that two of the constructs were eliminated based on our analysis. Beliefs about preservice education was eliminated due to low loading scores for both items within this construct and impact was eliminated because it ended up having the same items included as outcome expectancy. The ISTEBI had a 5-point Likert scale (1-strongly disagree, 5-strongly agree).

Table 3

ISTEBI Items Based on EFA Results

Construct	Items	Original Cronbach's Alpha	Revised Cronbach's Alpha
Outcome expectancy	**12**, 13[b], 24[ab], **26**, **37**, **38**, 40[ab], 42[ab], **43**, **44**, 46[ab], **47**	0.59	0.72
Self-efficacy	**16**, **18**[a], **22**[a], **29**	0.49	0.49
Science confidence	17[ab], **33**, **36**, **39**, **41**[a]	0.67	0.79
Beliefs about preservice education[b]	15[b], 19[b]	0.34	-
Impact[b]	**12**, 13[b], 24[ab], **26**, 35[ab], **37**, **38**, 40[ab], 42[ab], **43**, **44**, 46[ab], **47**	0.56	-
Self-efficacy for inquiry science teaching	14[b], **18**[a], **20**, **21**[a], **22**[a], **23**, **27**, 28[ab], **29**, **30**[a], **31**, **32**, **34**, 35[ab]	0.76	0.81
Comfort with messy science	**18**[a]	-	-
Comfort with student control	**14**, **20**, **21**[a], **22**[a], 25[ab], **27**, **29**, **30**[a], **31**, **32**, **34**, 35[ab], **45**	0.75	0.82
Overall science teaching self-efficacy	All	0.82	0.86

[a] reverse coded

[b] Deleted items/Constructs

*items remaining in each construct have been bolded

Six additional items were created by the researchers to assess EPTS' self-efficacy related to knowledge, understanding and level of confidence toward the NGSS. These items had a 10-point Likert scale (1-no knowledge/no understanding/no confidence, 10-very knowledgeable, high level of understanding/very confident).

Qualitative Data Collection

Two types of qualitative data were collected during the project, interviews (EPSTs and K-8th grade participants) and field experience reflections (EPSTs). EPST interview questions focused on their experiences participating in the project (e.g., "How did your experience inform your future teaching", "How has your confidence changed with the NGSS", "What would you change about the LEGO activities"). For EPST reflections, guiding questions were provided ("Did you complete all the activities you planned," "If not, where in your lesson plan did you end," "What were some challenges your team had," "What would you tell the next group to help them before they teach their lesson," and "What did you learn through this experience"). They were asked to submit the reflection on the same day following the implementation of their lesson plan.

Group interviews were conducted with K-8 students at each site. Each group was asked the same four questions about their knowledge and experiences with science, engineering, math, and technology. The questions were (1) is science important; (2) what experiences have you had with science; (3) who uses science; and (4) would you be interested in a career in science? Each set of these questions was replaced with the words engineering, math, and technology respectively.

Analysis

To address Research Question 1, a correlation test was performed between participating EPSTs' perceptions of science (STEM Semantics Survey) and their overall self-efficacy related to teaching science (ISTEBI). To assess whether participation in the program changes EPST' beliefs and attitudes related to STEM (Research Question 2 and 3), a pre- and post-survey was administered. Differences were assessed using a Wilcoxon Rank Sum test as appropriate with non-normally distributed data. For the ISTEBI, sum scores were compared, and for the NGSS related items, individual scores for each item were used.

Random imputation of missing values was performed to create a complete data vector for variables used in the analysis. This technique is more appropriate for handling missing data than other approaches such as listwise deletion or mean imputation (Gelman & Hill, 2006).

Interviews with the K-8 students and EPSTs were transcribed. Written reflections from EPSTs were collected electronically. These qualitative data were analyzed looking for commonalities and themes among responses in the participants' experiences. To ensure trustworthiness of data, two of the researchers on the project coded data separately then reached consensus on themes. These data provided support in addressing Research Question 2 through 4.

Results

EPST Participants – Research Question 1

To address Research Question 1, a correlation test, using a Pearson correlation coefficient, was computed to determine how EPTSs' perceptions of science related to their overall science self-efficacy. There was a significant, positive correlation between the two variables [$r=0.50$, $N=60$, $p<0.001$], as seen in the scatterplot – Figure 1.

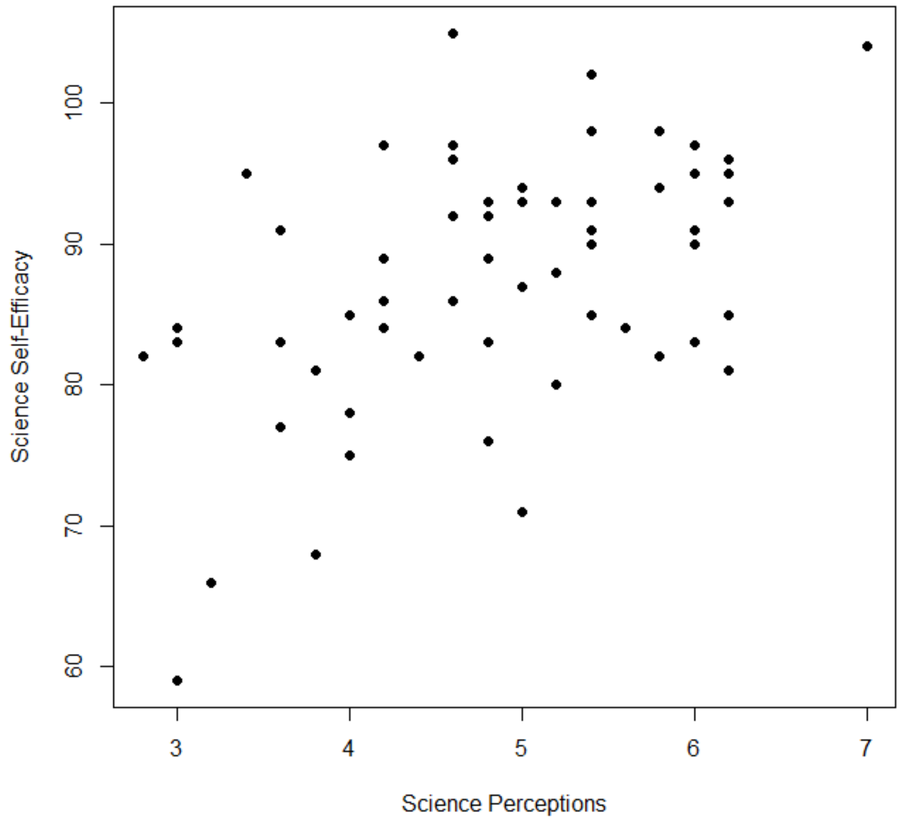

Figure 1. Scatter plot of Science Self-Efficacy versus Science Perceptions for EPSTs on the pre-survey.

Although there was not a significant correlation between EPSTs' Science Perceptions and their knowledge and understanding of the NGSS, there was a significant correlation between their Science Perceptions and their confidence in teaching the NGSS [r=0.29, N=60, $p<0.05$] and confidence with the engineering design strand within the NGSS [r=0.30, N=60, $p<0.05$].

EPST Participants – Research Question 2 and 3

Table 4 shows the results of a Wilcoxon Rank Sum test analyzing pre- and post-survey results for the participating EPSTs. None of the constructs relating to EPSTs' ISTEBI survey items were statistically different, although there were increases in the means from pre to post for all of the 8 constructs. Each of the items related to knowledge, understanding and confidence toward the NGSS were highly significant with a higher mean on the post-survey.

Table 4

Wilcoxon Rank Sum test, pre-post survey results with participating EPSTs

Beliefs and Attitudes about Teaching Science (Scale: 1[Strongly disagree] – 5[Strongly agree])	Range	Pre-Survey Mean(SE)	Post-Survey Mean(SE)	Sig.
Outcome Expectations	7 - 35	22.33(0.46)	23.11(0.44)	-
Self-efficacy	4 - 20	14.23(0.24)	14.74(0.26)	-
Science Confidence	4 - 20	14.25(0.35)	14.72(0.35)	-
Self-efficacy for Inquiry Science Teaching	11 - 55	40.90(0.59)	41.13(0.58)	-
Comfort with Messy Science	1 - 5	2.93(0.11)	3.11(0.12)	-
Comfort with Student Control	11 - 55	41.80(0.59)	41.89(0.56)	-
Overall Science Teaching Self-efficacy (All)	25 - 125	87.50(1.15)	90.08(1.19)	-
Knowledge, Understanding and Confidence toward NGSS (Scale: 1[None] – 10[Very])				
Knowledge of NGSS		2.07(0.21)	6.19(0.24)	***
Knowledge of Engineering Strand within NGSS		1.48(0.12)	4.55(0.29)	***
Understanding of NGSS		1.97(0.18)	6.23(0.22)	***
Understanding of Engineering Strand within NGSS		1.40(0.11)	4.47(0.29)	***
Level of Confidence in Teaching the NGSS		2.15(0.20)	5.68(0.24)	***
Level of Confidence of Engineering Strand within NGSS		1.90(0.18)	4.47(0.25)	***

***$p<0.001$

In addition to survey results, researchers analyzed interviews and lesson reflections, which helped deepen their understanding of the impact the LEGO project had on EPSTs. Four themes emerged from these data. The first theme, Unfamiliar Territory, related to EPSTs working with a more diverse group of students (English language learners, students from a low socioeconomic household) than they had typically experienced in their prior field work. The second theme, Firsthand Experience, related to EPSTs recognizing the value of the authentic teaching experience they were getting in working with students. The third theme, The "Wow" Moments, related to EPTSs' surprise at the ability and ingenuity of K-8th grade children working with the engineering challenges that were posed. Lastly, Building Skills related to new experiences of the preservice teachers that helped them strengthen their pedagogical teaching skills.

K-8 Elementary-aged Students

The final research question was exploring K-8th grade students' knowledge and experiences related to STEM. Seven themes emerged from these data. The one theme emerging for Science was Science as Experiential, with students relating the content to experiencing it in the world around them, through experiments or with other school activities. For example, one student indicated that science was about “growing plants” (Interview #1). Conversely, students viewed Math as Practical, such as skills needed for assessment, or Math as Computation, such as “adding and subtracting” (Interview #1). The students' described Technology as Assessment when discussing it in a school setting, such as being used to test students’ reading and math abilities. When asked if students use technology at school, one student replied, "Yes, we do STAR reading" (Interview #1). However, outside of school, students described Technology as Helping Others. For example, one student indicated “One time my brother’s computer wasn’t working, then I fixed it. Parents and grandparents do not know technology so they call for me to fix it” (Interview #7). Engineering ideas focused primarily on Building and Fixing. This is evident by the students' responses about engineering. “Like building cars and stuff. Because if your car ever breaks down you can know how to fix it.” (Interview #5). However, a few students described Engineering as Innovation, such as creating new technology.

Discussion

Elementary Preservice Teachers

In this study, we set out to better understand the influence that an after-school robotics program had on EPSTs. Our initial analysis was to determine whether or not a correlation existed between EPSTs’ science self-perceptions and their science self-efficacy as well as their self-efficacy related to their knowledge, understanding, and level of confidence with the NGSS and engineering strand within the NGSS. As might be expected, researchers found a moderately, significant positive relationship between EPSTs’ science perceptions and overall science self-efficacy. However, the only significant correlation between EPSTs’ science perceptions and NGSS related to their level of confidence in teaching the NGSS and with the engineering strand within the NGSS. Interestingly, there was not a significant correlation between science perceptions and EPSTs’ knowledge or understanding of the NGSS.

When considering changes over the course of the semester, results indicated no significant differences pre to post for EPSTs’ beliefs related to STEM. However, findings did indicate significant differences in their self-efficacy beliefs related to the NGSS. Even though means were higher for the post-survey across all beliefs and attitudes about teaching science, it is possible that the semester-long after-school program was not broad enough to general science or sustained long enough to yield significant changes in these beliefs and attitudes. With regard to the self-efficacy beliefs related to the NGSS, the focus of the field experience on the engineering design process and the engineering standards within NGSS might provide insight for changes that were found. EPSTs were advised to create a lesson using the engineering design model described by Engineering is Elementary (www.eie.org). These lessons often followed a sequence of students being presented with a challenge/problem, imagining solutions, planning, designing, testing, and redesigning. The authentic nature of the community-based field experiences may have helped to make them more meaningful for EPSTs in terms of how they would apply the NGSS within a classroom setting. These results align with findings from other research connecting authentic teaching experiences and changes in self-efficacy for teachers (Flores, 2015). EPST interviews provided helpful insight into working with the K-8th students and the unique after-school setting.

EPST Interviews

In interviews and written reflections, EPSTs reported that working with a diverse population of students was a major benefit of their collaboration with the LEGO robotics after school project. "Working with … minority and just the different age groups … because I haven't been in a situation with … all those different minorities" (Interview 3). This response seems to indicate a general lack of experience working with students that are ethnically and socioeconomically different than them. Having experiences teaching in this unfamiliar territory gave EPSTs new perspectives and skills to use as future teachers.

In addition, EPSTs reported that they were impressed with the creativity of the students' use of technology. This poses a question about EPSTs' preconceived expectations of what students from low-income backgrounds can do. If they truly had high expectations and believed that all students could learn, regardless of their background, then why was it a surprise for them to see children working with technology in such a creative manner? For example, one student stated the following:

> It doesn't matter what the students' socioeconomic background and where they come from or anything, they're always gonna be inquisitive kind of builders you know and um kids love putting things together, creating things you know using your imagination and um building things and so I learned that that's something that you can definitely tap into you know, no matter who the student is (Interview 2).

This conflict could hint at EPSTs' struggling to reconcile their beliefs with what they were experiencing when teaching their lessons at the community sites. Changes in preservice teachers' beliefs is difficult and complex (Darling-Hammond, 2006; Korthagen, Laughran, & Russell, 2006); however, change is possible, even over the course of one semester (Sheridan, 2016) as shown again in this study.

Gaining greater confidence in knowledge of the Next Generation Science Standards and using these standards to plan appropriate lessons was another area of growing confidence for the EPSTs. This knowledge gain is reflected in the quantitative data and supported in their interviews when asked about their confidence teaching the NGSS. Noticeably the immediate use of new knowledge in a practical setting makes a difference in terms of self-efficacy in using the NGSS effectively in lesson planning and implementation. This immediate use gave them an opportunity to learn and grow in confidence as described by an EPST in Interview 3: "Honestly, going into it, I was really nervous, but after having the experience that we did with just the class and like this experience (LEGOS) I'm pretty confident in them [NGSS]." In these real-life situations EPSTs have the opportunity to put theory into practice allowing for valuable learning experiences (Darling-Hammond, 2012). EPSTs described understanding that remaining flexible in both lesson planning and management of students is possible.

> We learned that sometimes things don't go as planned and you will always need to think quick [sic]on your feet. Our group really stepped up and decided on a quick thinking lesson that we could implement quickly that we were all comfortable with and it allowed us to have a great lesson plan. Just be prepared for anything, because things do happen that are out of your control (Reflection 1).

This statement is also reflective of the survey data because EPSTs were grappling with the idea of student control in the classroom. As participants were responsible for creating their own structure at these community sites, they experienced some dissonance with their initial beliefs about their ability to create a productive learning environment when students were partly in control of the learning process. Learning to give up control of the learning process is important in a student-centered classroom (Alderman & MacDonald, 2015; Gorman & Larson, 2012). Particularly in STEM, exploring concepts, solving problems, experimenting, and drawing conclusions need to be student driven and facilitated by the teacher (not led by), which allows for deep understanding of content to occur. For EPSTs, this experience allowed them the chance to practice these skills with students and gain valuable insight that they might not have otherwise experienced prior to student teaching. K-8th grade students also provided valuable insight to this study.

K-8th Grade Children Interviews

K-8th grade children discussed experiences with science, technology, and math. Students described engineering as fixing or building. "Like building cars and stuff. Because if your car ever breaks down you can know how to fix it" (Interview #5). Comments related to engineering were based on perceptions of this field rather than experience. For example, children likely have been exposed to engineering tasks such as building with blocks, fixing a bike, or even using LEGOs, but if these activities are not formally identified as engineering, they do not describe them as such (Robinson, Adelson, Kidd & Cunningham, 2018). So, when asked, they may lack the vocabulary to identify their experiences as engineering.

With regard to science and technology, children noted hands-on experiences that connected back to their home life. For example, when referring to science a student said "I learned at home I like to go outside when it's warm and look at the bugs and insects. Like I put them in a jar and look at them" (Interview #7). Whereas another student connected technology with helping others at home. "Whenever my dad uses the computer and doesn't know what to do, he asks me and then I do everything for him" (Interview #2). This theme may be evidence of the "Bottom-up" transmission of technology that research notes between parents and their children (Correa, 2013).

In addition to connections made at home, students also described hands-on activities in school for science. Science was described experientially, "Because you learn new things about earth in there. Like today, we had a project on… like last week, we had a project on building a house and it was about earthquakes. We took marshmallows and toothpicks and tape, and we made a house. And my teacher had a pan and Jell-O and he put the house on the Jell-O and then he shook it and then, it fell down" (Interview #2).

Perspectives and experiences with mathematics were mostly practical and computational. Several students related math to being a cashier and using money, however students' comments seemed disconnected from math learning. No connection was made between hands-on activities related and math. This does not necessarily mean they were not having these math experiences; students may not perceive classroom hands-on activities as math content. It is important to note that while engineering, science, and technology were all described in terms of hands-on, real-world connections or experiences, mathematics had limited descriptors outside of performing computations. Other research found similar results with elementary children who "associated mathematics primarily with number and arithmetic" (Grootenboer, 2003, p. 6).

Limitations

There are several limitations with this study. The first limitation was that changes in beliefs cannot be solely associated with participation in the community-based field experience, as EPTSs were also enrolled in a science methods course during the same semester. However, it is important to note that the science methods course, although focusing on inquiry methods, did not focus on the engineering design process. Additionally, EPTSs were more comfortable with the

LEGO kits used with K-3rd graders as it required little knowledge of programming or newly acquired skills. They needed extra encouragement and time to play with the LEGO Robotics kits.

Another limitation for the study related to data collected with elementary-aged children. The K-8 students, because of the nature of an afterschool program, were allowed to opt in or out of participating in the LEGO Robotics club each week. This changed the continuity of the group and knowledge and experience for these students each week. Although survey data were collected with the participating children, the lack of continuity of participation and the difficulty in collecting parent consent forms led us to exclude the data due to a low number of participants. Finally, collecting data and implementing lessons at the community sites posed challenges. There were many interruptions to teaching like intercoms and walkie-talkies used to call students to the front for dismissal. These interruptions were evident in interviews and during the LEGO Robotics club time.

Conclusion

With the new science standards adopted across the United States, there is a need for research that will provide a better understanding of how education programs can integrate meaningful learning and teaching experiences for preservice teachers related to these standards. Knowing the connection between teacher beliefs and their practice (Aguirre & Speer, 1999), it is also important to investigate how specific experiences within preservice teachers' education program influence their beliefs. This study provides evidence that field experiences influence preservice teachers' self-efficacy related to teaching science and the NGSS.

Because preservice teachers have little knowledge of engineering from their past experiences, it is essential to provide opportunities for them to try engineering. After-school programs could provide preservice teachers experiences in an authentic setting that could improve their practice. These types of programs could provide the integration of problem-based and project-based experiences, as found with LEGO robotics, that other research state to be critical experiences for preservice teachers (Jeffers, Safferman, & Safferman, 2004). In addition, after-school programs provide an authentic way of incorporating the engineering design process, which is essential for inclusion in the elementary curriculum (Nadelson, 2015).

When considering children's experiences with STEM, an after-school program such as the LEGO program might provide them with experiences to try on different identities, such as being an engineer. With research indicating that that K-8 students have false perceptions of engineering (Capobianco, Diefes-Dux, Mena, & Weller, 2011), an after-school program may provide students with experiences that change the way they perceive what it means to be an engineer. One thing to keep in mind with these types of programs is that students may not recognize that activities involving LEGO robotics correlate with ideas about science, engineering, and math unless teachers explicitly make those connections (Dixon, 2012). While there were some connections to engineering and innovation in the interviews with children, most of the children referred to engineering as building and fixing things despite their experiences over the course of the semester. It is possible that participation in these types of engineering-based activities needs to be more consistent and prolonged to change their views about what engineering is as a discipline. Because research has highlighted the benefit of these informal opportunities (such as LEGO robotics), such as increasing students skills within the STEM disciplines (Katehi et al., 2009) and attitudes related to STEM (Weber, 2012), it is promising to continue to provide these types of programs for children. Benenson, Neujahr, Seignoret, and Goldman (1997) state that children need to learn how to develop, build, and test their own designs. It is important that we, as teachers, provide students opportunities to investigate their surroundings, problem solve, design and build, and make adjustments to their designs. "By encouraging children to look more deeply at the artifacts around them and engage in the making of such artifacts, they will be developing their 'engineering intuition' and learning to use this 'engineering perspective' as their own" (Erwin, 1998, p. 3). This is exactly how engineering experiences should be created for children.

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Appendix A

Elementary Preservice Teacher Reflection and Interview Data

Theme/Pattern	Example Evidence
Unfamiliar Territory	• "I guess just working with the kids, because I've never really worked with low-income kids before, um, and so that was beneficial, just learning how to motivate them and keep them on task, and just keep them excited about things. I think that was beneficial" (Interview 1). • "While working at the Housing Authority and with the LEGOs, I will have to say that I benefitted from being exposed to different cultures" (Reflection 5) • "Students that come from, you know, lower socioeconomic brackets, you know those schools that have 75 to 100 percent free and reduced lunch, um you know there's an attitude that some of the students have that they recognize the situations they're in, I'm and they have these-these um false expectations they put on themselves, you know, I'm at the poor school. I'm at the dumb school, I'm dumb, I'm not smart, I can't achieve anything" (Interview 2).
First-Hand Experience	• "I feel pretty confident, it's you know, you have all the materials with you and explaining them, it's mainly just adapting them to a lesson and including them; making sure the students are learning those certain standards" (Interview 2). • "Honestly, going into it, I was really nervous, but after having the experience that we did with just the class and like this experience (LEGOS) I'm pretty confident in them" (Interview 3).
The "Wow" moments	• "There are so many ways that children think about things whenever you pose a problem to them, which is um how we went about our lesson so we could really see how the children thought and it's a very good hands on experience for them which and they absolutely love it" (Interview 3). • "I mean, I was impressed whenever we turned the motor on. I was like, 'Oh my gosh this is crazy!' I mean its still, I mean I'm…I've been raised in this world with technology and I'm still consistently impressed by technology and what kids can do with technology. And so it was really impressive to watch like us give them instruction and them run with it. And all the things they (LEGOs) would do" (Interview 1).

	• “Our group learned that the students loved having the freedom to choose from a variety of objects to build instead of being limited to one single object. This allows them to build something that interests and excites them. This experience also proved that students love doing hands-on activities” (Reflection 10).
Building Skills	• “Through this experience we agreed that it was interesting to work together at the same level as the students to figure out how to assemble these robots. Since we didn't know what we were doing either it was an interesting dynamic that was different than the usual classroom setting where the teacher "knows all of the answers (Reflection 6)." • “We feel like we learned how to be more flexible and remember that even plans can get messed up. You have to roll with it and not show students you are frustrated or frazzled because they will feed off that behavior (Reflection 8).” • “Through this experience, my group learned how to improvise. We learned how to make the best of the situation and still try to show the students something new (Reflection 4).”

Appendix B

Themes and Examples for K-8th Grade Student Interviews

Theme/Pattern	Example Evidence
Science as Experiential	• "Because you learn new things about earth in there. Like today, we had a project on... like last week, we had a project on building a house and it was about earthquakes. We took marshmallows and toothpicks and taped, and we made a house. And my teacher had a pan and Jell-O and he put the house on the Jell-O and then he shook it and then, it fell down" (Interview #2). • "We built a volcano. And tornadoes" (Interview #5). • "I learned at home I like to go outside when it's warm and look at the bugs and insects. Like I put them in a jar and look at them" (Interview #7).
Math as Practical	• "Yeah, if I ever worked at a grocery store" (Interview #2). • "And for your (state assessment)" (Interview #4). • "Yeah if you were a cashier, and the register was down you would have to know how to calculate the tax and everything so you don't over price, or underprice different things" (Interview #7).
Math as Computation	• "I've used decimals on projects..." (Interview #1). • "Calculators for a math test, yeah" (Interview #3). • "I think math is interesting because you have to do subtracting, adding..." (Interview #4).
Technology as Assessment	• "We use technology for tests in computer to see who did AR a lot" (Interview #1). • "We had made a PowerPoint" (Interview #1). • "(it's important because)...You can do homework on technology" (Interview #5).
Technology as Helping Others	• "Whenever my dad uses the computer and doesn't know what to do, he asks me and then I do everything for him" (Interview #2). • "One time my brother's computer wasn't working, then I fixed it. Parents and grandparents do not know technology so they call for me to fix it" (Interview #7). • "Cause...I'm good at getting on stuff for my granny and all that" (Interview 6).

Engineering as Fixing or Building	• "Because they fix trains to go on the track" (Interview #2). • "Like building cars and stuff. Because if your car ever breaks down you can know how to fix it" (Interview #5). • "Engineering is very important because you get to learn new words and find out how to fix stuff" (Interview #3).
Engineering as Innovation	• "Ummm…make better stuff like Apple would be an engineering thing because they're making more advanced technology" (Interview #7). • "I think that just about everybody engineers because when you think of something new, that's engineering. So everyone is an engineer" (Interview #7).