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I Can Be an Engineer: Using Problem-Based Learning to Enhance Students' Engineering Experiences (Fundamental Research)

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Abstract

This research study investigates elementary students' experiences regarding engineering as a result of engaging in STEM-integrated problem-based learning (PBL) units. The study participants comprised fourth-grade students from the Southwest region of the USA. A mixed methods approach was employed for analysis. The qualitative findings revealed that STEM-integrated PBL promoted students to use authentic engineering skills such as engagement in design and engineering, teamwork, and communication. Students also indicated that PBL units enabled active learning, allowing them to control their learning experience, which fostered a more positive attitude in STEM. The quantitative findings corroborated the qualitative results, as a shift in students' attitudes was observed from pre to post. Many students who initially believed they could not be successful in engineering (56%) became more comfortable with engineering (98%). Furthermore, those that initially thought engineering could not improve everyday things for people (44%) felt engineering could afterward (87%). While those that believed (pre) fixing things was not something they were good at (38%) later felt it was something they could achieve (92%).

Introduction

Engineering education has gained prominence in STEM education, with the integration of engineering practices in the Next Generation Science Standards for K-12 education signifying the importance of engineering in pre-college education. Research suggests that integration of engineering in STEM can improve students' learning in science, mathematics, and technological literacy as well as stimulate students' interest in pursuing engineering [1]; [2]. Moreover, engineering education enhances students' problem-solving skills, as it provides real-world connections and opportunities for students to learn to manage uncertainties as well as ill-structured problems for learning [3]; [4]; [5].

Studies have investigated the degree of impact STEM and engineering education have on elementary school students [6]; [7] as elementary school years are known to be a critical time to spark students' interest in STEM [8]. The focus of our study is promoting engineering as an integral part of the elementary curricula. In this study, we examined the students' experiences with and attitudes toward engineering after engaging in STEM-integrated problem-based learning (PBL) since negative attitudes can influence students' interest in engineering and impact future career choices [8].

Background

Problem-Based Learning (PBL)

Problem-based learning (PBL) is a student-centered instructional approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge to solve ill-structured problems. In PBL, learners work together in collaborative groups to construct understanding through problem-solving [9], [10]; [11]. Through engagement in the problem-solving process, learners acquire knowledge and develop higher-order thinking skills [11]. PBL is based on the idea that learners should not be passive recipients of knowledge because passivity hinders a deep understanding of the presented material and its application to real-world situations [12]. The instructor in the PBL environment serves as a facilitator who guides the learners as opposed to providing direct instruction [9]; [10]; [11]. Based on the literature, PBL is an effective instructional pedagogy that "can help bridge the gap between the engineering classroom and real-world practice" [13, p. 3].

PBL pedagogy is not novel and has been employed for many years to teach multiple disciplines in pre-college and higher education [9]; [10]. It has become a widespread instructional methodology in "disciplines where students must learn to apply knowledge" [14, p. 1]. PBL can potentially engage students in engineering through real-world design problems [11]; [13]. The ill-structured problems can provide learners with experiences necessary for "navigating the complexities and variables often encountered in industry practice" [13, p. 1]. Through these experiences, students can develop high-order thinking skills and gain engineering knowledge [10]; [13]. Rehmat et al. [10] investigated the impact of PBL on elementary students' content knowledge and critical thinking skills and found a significant difference between the traditional learning and the PBL group. Sarı et al. [15] investigated students' attitudes toward STEM after engaging in PBL activity. They found that students' attitudes toward STEM disciplines and STEM career interests in STEM-related occupations significantly increased after their engagement in the PBL activity.

Attitude towards STEM

Attitude is a learned trait by an individual, either actively or by vicarious experiences, that is receptive to change [16]. An attitude can be directed to a person, situation, group, policy, or abstract idea [16]. Students' attitude toward specific content is influenced by their environment, personal ambition, parental influence, and/or effective instructional methods [17]. Even though attitude is changeable, it is not a random occurrence; a specific event or situation has to be the catalyst for this change [16]. For example, students do not naturally like or dislike a particular subject; they learn to like or dislike it.

As STEM is seamlessly integrated into the workforce, preparing students with positive attitudes toward STEM is critical in equipping them with proper STEM skills and expertise for the future. Pre-college education has been putting effort into improving STEM attitudes in STEM fields [18] and designing various learning approaches and interventions in STEM [19] to spark students' positive attitudes. Studies exploring elementary students' STEM attitudes found that STEM integrated robotics curriculum resulted in students' positive attitudes toward math [19] and positive STEM attitudes relating to computational thinking skills [20].

Engineering education positively motivates students to learn STEM and develop an interest in STEM careers [21]; [22]. Although exposure to engineering concepts in STEM should start at an early age, a limited number of studies have examined the degree of impact engineering education has in elementary school [2]; [23]; [24]. In examining changes in elementary students' attitudes and perceptions of engineering after they engaged in different engineering challenges and concepts through the Engineering is Elementary (EiE) curriculum, Cunningham & Lachapelle [25] found that students developed positive attitudes toward engineering, with an increased interest in becoming an engineer and feeling more comfortable with related jobs and skillsets. Moreover, a STEM curriculum that was designed using an engineering design framework in designing a 3-D model plane contributed to an improved application of STEM disciplines among students [26].

All in all, for students to be excited and stimulated to pursue STEM-related careers, they must be provided with rewarding, meaningful learning experiences that aid in developing positive attitudes towards STEM professions from a young age. Knowing how students feel about STEM-related professionals can assist in creating opportunities for students to be mentored by practitioners in STEM fields and engage in integrated STEM practices that can promote a positive attitude towards engineering and STEM.

Theoretical Framework: Social Constructivism

Problem-based learning, which focuses on guiding students to develop self-directed learning skills, is theoretically grounded in seminal learning theories such as constructivism (Piaget) and social constructivism (Vygotsky), where learners construct knowledge actively in socially situated environments through interaction with others [27]; [28]; [29]; [30]. Social constructivism theory has been applied to teaching and learning for knowledge acquisition and instruction [27].

PBL follows a social constructivist role in learning since it promotes social interaction among students in the classroom while allowing them to apply their critical thinking process [27]; [29]. Through this engagement and exploration, students in a PBL environment solve complex problems while developing an understanding of the content. In PBL, the learning environment is democratic and student-centered, where the teacher is the facilitator [31]. The facilitator is responsible for providing guidance through scaffolding, modeling, and questions. This scaffolding fades as the student becomes more confident and experienced with PBL [31]; [32].

Similarly, in sociocultural theory [30], the advanced peer provides guidance to assist learners in reaching a new conceptual understanding [11], [31]. The theoretical groundings of social constructivist learning theory reinforce that PBL pedagogy is pertinent to the current study. Thus, using social constructivism as a theoretical framework to examine students' experiences and attitudes about engineering due to their engagement in the PBL STEM integrated units can provide new insights about how to influence students' interest in engineering and impact future career choices.

Research Purpose & Question

This study examines the underpinnings of engineering in STEM-integrated PBL by investigating students' experiences and attitudes toward engineering due to engaging in STEM-integrated PBL units. This study responds to the following research questions; (1) *How do students describe their engineering learning experiences in STEM-integrated PBL units?* (2*) What is the impact of problem-based learning on fourth-grade students' attitudes toward engineering?*

Methods

Research Design

A concurrent mixed methods approach (QUAL + quant) was employed in this study as one data analysis would be insufficient to ascertain the effectiveness of problem-based learning with its correlation to student engineering experiences and attitudes. A concurrent mixed method design allows the researcher to collect quantitative and qualitative data simultaneously, which can then be converged to provide an in-depth analysis of the research questions [33].

Participants & Setting

The student participants of this study were in fourth grade. There were a total of 52 fourth-grade students across the two classes. The demographic of the student population (n = 52) that participated in this study was 40 (76%) White/Caucasian, 4 (8%) Latinos/Hispanic, 3 (6%) Black/African American, 2 (4%) American Indian/Native American, 2 (4%) Asian, and 1 (2%) Pacific Islanders. The majority of the students were males, 27 (52%) and 25 (48%) females. The average age of the students was nine years old.

The teacher that participated in this study was a science specialist for the school and taught both classes involved in this study. The teacher holds a Bachelor of Arts in Elementary Education and a Master of Science in Secondary Education specializing in Mathematics. She was state certified to teach grades K-8 in mathematics and general science. In addition, she had over five years of teaching experience at the elementary level. The teacher facilitated the learning in this STEM-integrated PBL environment. The teacher was trained in PBL and participated in a pilot study before the actual study [10].

The study occurred at an elementary school in a large school district in the Southwestern United States. The implementation was approximately 17 weeks long during the second half of the school year. Science in this school was taught as a ‘special’ subject similar to art, music, and library rather than a subject within the classroom. Students in this study met for ‘specials’ once a week. The students met in the science classroom for the science special referred to as STEM. Additionally, each fourth-grade class had the science special on a different day of the week (i.e., Class 1 - Wednesdays and Class 2 -Thursdays). The science classroom was equipped with lab tables, desktop computers, and iPads. The teacher’s role in the school was to teach K-5 grade student STEM [10].

Context: The Engineering Unit

The students in these two classes participated in two STEM-integrated units, each focusing on a different problem scenario. One dealt with habitats, the other with earth processes and natural disasters implemented through problem-based learning methodology. The first problem scenario required students to learn about a trout's structure, function, and habitat. Information gathered about the trout was used to design a prototype of an aquarium habitat for the classroom. This aquarium was designed to mimic a trout habitat in which trout eggs were to be kept until they developed into a fry [10].

The second problem scenario required students to learn about the area's geology, plate tectonics, and possible natural disasters that can affect the region. After they understood the scientific core ideas, students used their understanding to design a prototype of a luxury apartment high-rise for Caesar Entertainment that can withstand an earthquake [10].

The unit was implemented using the five stages of the PBL cycle: problem *presentation, students' identification of the problem to be investigated, self-regulated investigations, data organization, and sharing of their findings* [10], [11]. The lesson commenced with the teacher presenting the problem, followed by students reviewing it again within their group to brainstorm and discuss their ideas. Students, within their groups, compiled their ideas on the 'Need to Know' chart.

In the 'Need to Know' chart, students identified, "*What do you know*?" followed by, "*What do you need to know*?" and finally, "*How can you find out what you need to know*?" Students then divided tasks among group members and gathered information by conducting research. In the fourth stage, the team members compiled and organized the information or data they had collected. This was followed by each team conceptualizing, designing, and testing their prototype. Finally, in the fifth stage, each team had to give an approximately 10-minute presentation. They shared their model, identified the materials they utilized for their prototype, and explained their solution to the problem. For the high-rise activity, during the presentation, the teams had to simulate an earthquake shake test to demonstrate the building's ability to withstand a possible earthquake. Once every group had presented, the entire class reflected on the problem and discussed each team's prototype or model [10], [11]. Throughout the study, the teacher facilitated the learning through questioning and engaging in student discussions while monitoring students' learning. The students were also encouraged to ask questions and interact with their peers.

Instruments

This study comprised multiple data sources: an open-ended questionnaire, classroom observation, and an S-STEM survey. The open-ended questionnaire consisted of five questions designed to probe students to share their experiences of the problem-based learning environment. The students were provided the opportunity to address their likes and dislikes regarding engineering learning through PBL and describe the strategies they used to solve each problem scenario [10]; [34].

Classroom observations were conducted throughout the duration of the study. The comments entailed the teacher and the students. The implementation of the lessons, pedagogy, and the teacher's role were all documented. The students were observed to determine how they interacted with their peers within and outside their assigned teams, interacted with the teacher during the unit activities, and engaged throughout the units. The researcher played the role of a participant researcher and engaged in discussion with students without fully committing to member values and goals [35].

The upper elementary attitude S-STEM survey [18] was utilized to collect students' attitudes about STEM—the survey comprised 37 items. The survey focused on students' attitudes toward engineering and technology (Table 1). Participants responded to these items on a five-point

Likert scale ranging from ‘strongly agree’ (5) to ‘strongly disagree’ (1). The content validity of the S-STEM survey was reported as being established by a committee of five content experts and ten upper elementary teachers with a Cronbach’s alpha of 0.85 [18].

Table 1. *Engineering and technology items*

Survey Items	Scale
1. I like making new products.	Engineering and Technology
2. If I learn engineering, then I can improve things that people use every day.	Engineering and Technology
3. I am good at building or fixing things.	Engineering and Technology
4. I am interested in what makes machines work.	Engineering and Technology
5. Designing products or structures will be important in my future jobs.	Engineering and Technology
6. I am curious about how electronics work.	Engineering and Technology
7. I want to be creative in my future jobs.	Engineering and Technology
8. Knowing how to use math and science together will help me to invent useful things.	Engineering and Technology
9. I believe I can be successful in engineering.	Engineering and Technology

Data Analysis

A mixed methods approach was employed for analysis. A thematic analysis was conducted on the open-ended questionnaire and classroom observations to understand students’ experiences engaging in STEM-integrated PBL. First, the analysis was initiated by both researchers coding the questionnaires, and the classroom observation notes individually to identify the initial themes [35]. Through a reduction process, initial themes from each researcher were discussed and revised to identify themes that address the research questions. Finally, the modified themes were cross-checked across all data sets and grouped under more prominent overarching themes. Inter-rater reliability between the two researchers was 86%. Any disagreements between the researchers’ coding were discussed until a mutual agreement was reached. The whole process was continuous and one that built on itself [35]. Trustworthiness was established through the triangulation of data and multiple coders.

Afterward, descriptive statistics were used to capture changes in students’ attitudes toward engineering. Specifically, we examined the engineering and technology scale (pre-post) to determine if students’ attitudes towards engineering changed due to their engagement in the STEM PBL units over 17 weeks. For data analysis purposes, the agreement options (strongly agree & agree) were merged to represent ‘Agreement,’ and the disagreement options (strongly disagree & disagree) were combined to represent “Disagreement.’

Results

The qualitative findings revealed that STEM-integrated PBL promoted students to use authentic engineering skills, such as *engagement in design and engineering*, *teamwork*, and *communication*. Students also indicated that PBL units fostered *active learning* since it allowed them to control their learning experience, which fostered a more positive attitude in STEM.

Authentic Engineering Skills

Focus on Design and Engineering. The *focus on design and engineering* skills refers to incorporating design and engineering within the STEM-integrated PBL environment. The problems presented required students to design solutions and then create prototypes. Students particularly liked the design and engineering aspect of the STEM-integrated PBL environment. Students' excitement is summarized in the following statements, "I liked working with everybody in my group [team] and engineering these two things that I thought I could never engineer" (S#14453). While another added: "Being able to build/engineer things was really interesting" (S#1445). Similarly, another stated, "I enjoyed building and liked the designing process" (S#14483).

Students also expressed that the STEM content areas merged as one subject in the PBL units. As illustrated by the following statement, "I liked using science, math, computers, and engineering all together" (S# 14489). While another pointed out that it made the student feel like an engineer, "building was great, felt like an engineer" (S#14483). Likewise, a student claimed, "The clss [*sic*] was so much fun and engaging, we learned a lot...it was different, I got to be an engineer and [a] scientist" (S#14498).

Additionally, field notes from classroom observation revealed that students were actively involved and immersed in designing their prototypes. Throughout the unit, students focused on finding possible solutions to the problem. They searched, read, and engaged in discussion throughout the activity, especially during prototyping and testing. For instance, students in a group discussed the best design for their earthquake-proof building, "I like this [pointing to one of his group member's design] because the bottom [base] looks strong, so it will make it hard for the building to collapse during an earthquake" (S#14453).

Teamwork. The *teamwork* skill refers to the students working together in groups to provide solutions to STEM-integrated PBL problems. Students expressed that they liked working in teams and collaborating with their peers. One student stated, "Working together in a team at the end [leads to] success" (S#14479). Another student mentioned, "I like doing teamwork" (S#14466). Whereas another student expressed, "I liked that we worked together, we shared what we knew and then figured out what we [need to] learn so [we] can build our prototype" (S#14490).

This was also evident during classroom observations as students actively collaborated with their team members throughout the implementation. In addition, they were also engaging across teams if a team needed assistance. For example, one group member from a team walked over to a peer and friend on another team, requesting assistance with searching for information about filters for the trout aquarium. The friend walked over to assist and even shared the website his team reviewed. Throughout the classroom observation, students asked each other questions, discussed planning their designs, and collaborated with their teams when collecting data. Some teams also decided to divide tasks between each member to be efficient. In one case, one team divided tasks among the four group members. This team comprised of two boys and two girls. One of the team members (a female member) decided to divide the task between the groups. She stated, "I think we should split up." The group agreed. She continues, "I will look up information [points to a book about earthquakes], and you two (referring to other group members) can start thinking about the design and gather the materials". The team split and began working on their assigned tasks.

Communication. *Communication* skills refer to students exchanging information (e.g., discussion) with their team members, peers, and/or teacher. Students' engagement in the STEM-integrated PBL promoted communication during teamwork and when students were immersed in finding solutions for the problems. For instance, a student noted, "It was fun and challenging. We got to talk in our groups, and the teacher walked around and asked questions" (S#14494). Similarly, another student pointed out, "It was cool, everyone worked together, talked to each other, and we actually got to build and present at the end. I learned a lot" (S#14484). The unit, coupled with PBL, fostered an environment that promoted communication, active engagement, and teamwork.

Furthermore, field notes from classroom observation revealed that through the units, student-to-student and student-to-teacher interaction and discussion were highly visible in the PBL environment. Students had content-related conversations with their teammates, and the teacher walked around constantly, asked questions, interacted with groups, and provided guidance. At the end of each unit, the student groups had an opportunity to present their final solutions.

Active Learning

The theme of *active learning* refers to increased student-to-student and student-to-teacher interactions within the STEM-integrated PBL environment. Active learning emphasizes the application of theory and concepts by involving students in the learning process through problem-solving, group discussions, and peer interactions. In the PBL environment, this interaction encouraged students to think deeply, reflect, and be self-regulated learners. Many of the students' responses and field notes from class observations that described their overall experience with PBL fell within this theme. Several students claimed they enjoyed group interaction as it allowed them to control their learning experience. For example, many students described their active learning as 'cool,' 'fun,' 'exciting,' and 'amusing'. One student stated, "It was fun working with friends. I learned a lot" (S#14464). Another student claimed, "It was very fun, amusing, and lots of learning together with friends" (S#14460). Another student stated, "This was an active, fun lesson, and we worked in groups" (S#14488). Similarly, another student noted, "It was fin [*sic*], cool, and engineering is more fun than I thought, and the class was interactive" (S#14490).

Students' responses to the questionnaire support classroom observations as during the duration of the activity, students were focused on their work and collaborating with their peers in their group. During both units, students were actively engaged in the learning yet focused on the task.

For instance, a student from one of the groups returns to his group after gathering information and states, “Guys, I just learned that a trout lives in cold water, so we need to find a way to keep the water cold” (FN, S#14460). This led the group to delve into an in-depth discussion about their design and elements to reconsider.

Attitudes towards Engineering

Further investigation of the individual engineering and technology items on the STEM survey (S-STEM) was conducted to determine if any changes occurred in students' attitudes from pre to post (See Table 2).

Student agreement with statements focused on positive attitudes towards engineering increased from pre- to post-surveys for all nine survey items. Conversely, student disagreement with statements decreased from pre-to-post surveys. Neutrality also decreased from pre- to post-surveys, with the percentage of students answering neutral for the nine survey items being lower in the post-surveys than the pre-surveys.

Survey item Q3 “I am good at building or fixing things.” had larger percentages of students disagree than agree with the positive statements in the pre-survey. This was interesting because, for the remaining survey items, the majority of students were overall in agreement with the statements to start with, meaning that while the students already had positive attitudes towards the statements, the percentage of students in agreement still increased. For Q3 specifically, most students disagreed with the statements to start with and changed from disagreement to agreement in the post-surveys. The most striking finding with these items on the STEM survey was that 98% of the students agreed with the statement “I believe I can be successful in engineering.” (Q9) in the post-survey.

Table 2: Students' attitude towards engineering (pre-post)

Items	S-STEM Pre			S-STEM Post		
	Agreement	Disagreement	Neutral	Agreement	Disagreement	Neutral
ET1	63%	23%	13%	96%	2%	2%
ET2	44%	37%	19%	87%	8%	6%
ET3	38%	44%	17%	92%	4%	4%
ET4	54%	23%	23%	92%	4%	4%
ET5	40%	29%	31%	94%	0%	6%
ET6	60%	21%	19%	94%	2%	4%
ET7	62%	23%	15%	94%	2%	4%
ET8	54%	27%	19%	98%	2%	0%
ET9	56%	25%	19%	98%	2%	0%

Further examination was conducted on a subset of students (See Figure 1). For this investigation, we purposively selected only those students whose experiences were highlighted in the qualitative analysis (n=12). We chose these students since we were curious if the change in attitude towards engineering was also evident among these individuals who positively described their experiences. In Figure 1, ‘Agreement’ is the sum of agree and strongly agree; ‘Disagreement’ is the sum of disagree and strongly disagree. The unaccounted percentages are for those that stayed neutral.

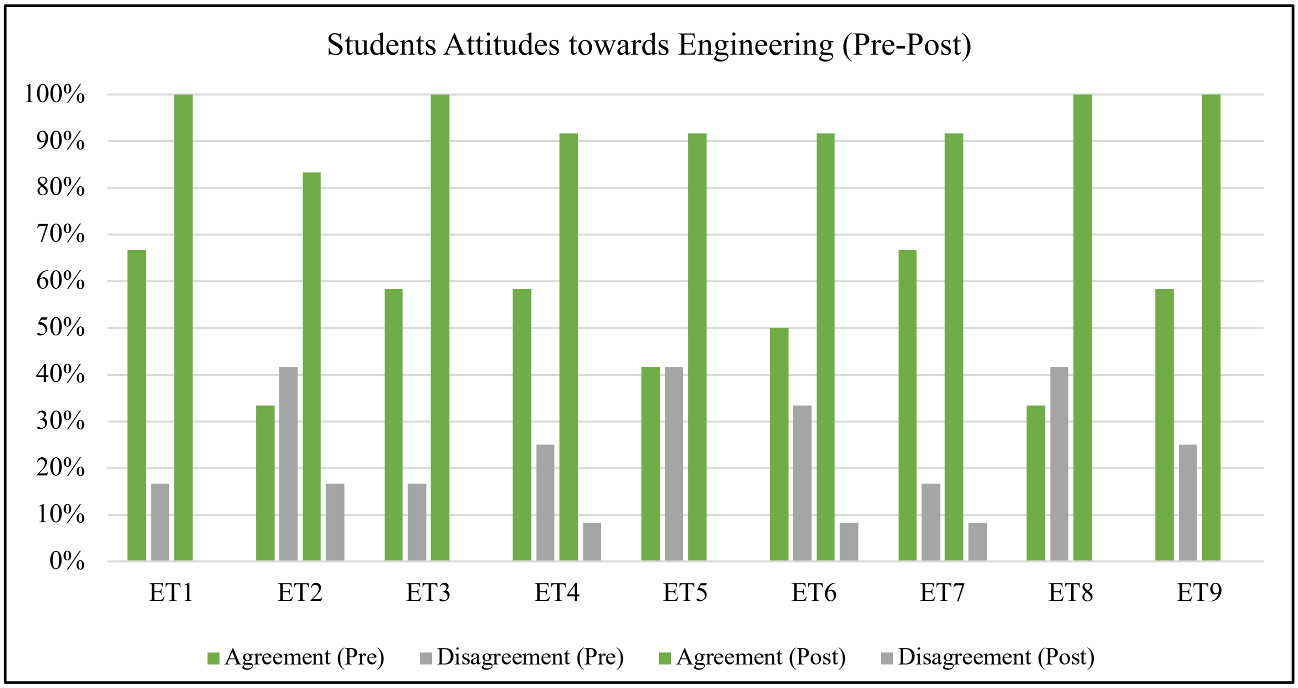

Figure 1. Changes in attitude towards engineering (n=12).

For the students who positively described their experience, the change in attitude towards engineering corroborated with their comments. For all nine survey questions, students had a higher percentage of agreement with the positive statements concerning engineering and technology. The percentage of students that disagreed with the statements was still less than the overall percentage that agreed. For half of the questions, all 12 students completely agreed with the statements in the post-survey.

Discussion

The results of this study contribute to the effectiveness of PBL pedagogy as a means to engage students in engineering learning. Several findings are clear. First, the added level of design and engineering provided students with a hands-on approach to learning science while engaging them in the engineering design process. Students mimicked field professionals as they conceptualized their designs into actual prototypes. For example, they had to identify the problem, search for possible materials, understand the properties of those materials, and then find consumable materials that could be used to build their prototypes (i.e., a compressible material to dampen the seismic response on the structure).

As they engaged in the PBL units, students utilized their understanding of science and math concepts coupled with the engineering design process to solve the problem. This seamless integration of multiple contents, including engineering, in the PBL units demonstrates the impact PBL has in promoting positive attitudes in engineering, which can lead to a developing interest in STEM careers. The finding also supports the seamless integration of STEM subjects through PBL. As Purzer et al. [36] suggest, integrated activities can potentially develop young children's interest in STEM. The inclusion of engineering in the STEM curriculum can stimulate curiosity and creativity among young children [36].

Secondly, PBL fostered an environment that promoted authentic engineering skills such as design and engineering, teamwork, and communication. Through instruction, the teacher created an interactive environment. Though the teacher didn't require students to divide tasks among the group members, some teams did as they thought it would be most productive for their time, illustrating a collaborative environment. Students experience is supported by research that PBL is a student-centered approach in which problem-solving and collaboration lead to knowledge acquisition [9]; [10]; [11]; [31]. Through this constant interaction, independency, dialog, and active involvement, students can find feasible solutions to multifaceted problems [11] [31]. The PBL environment allows students to share resources, ideas and work as a team. This partnership encouraged students to develop and maintain positive group learning behaviors.

Thirdly, PBL positively influenced student attitudes toward engineering. While most of the student participants already had a positive or neutral attitude towards engineering and technology, inclusion in the STEM-integrated PBL environment resulted in students believing that they were good at building or making things but, more importantly, that they could be successful in engineering. For the students who agreed with the positive statements, this experience reinforced what they knew to be true. For the students who changed their viewpoint and now have a more positive outlook on engineering and technology, this experience exposed them to the potential for different future opportunities. These students now all collectively agree that they could be successful in engineering.

Conclusion

STEM integration implemented through PBL can provide students valuable learning experiences while improving their attitude toward engineering. This study attempted to highlight that STEM-integrated PBL units can offer students holistic and meaningful real-world experiences, which can prepare them for their future careers. Student engagement in STEM-integrated PBL provided rich learning experiences and supported the development of authentic engineering skills, such as engagement in design and engineering, teamwork, and communication. Students also indicated that PBL units promoted active learning since it allowed them to take control of their own learning experience, which fostered a shift in a more positive attitude towards engineering.

This research is novel in understanding students' experiences associated with STEM-integrated PBL units and their attitudes toward engineering. PBL is a challenging pedagogy to implement in the classroom; therefore, it is the coupling of pedagogy with content that produces positive outcomes. This study provides implications for the importance of the PBL method to teach engineering curricula in elementary education and the importance of including engineering curricula in elementary schools.

References

[1]. L. Katehi, G. Pearson, and M. Feder, "*Engineering in K-12 education: Understanding the status and improving the prospects*, "Washington DC: National Academy Press, 2009.

[2]. J. Yuan, C. Kim, L. Vasconcelos, and M. Y. Shin, C. Gleasman, and D. Umutlu, "Preservice elementary teachers' engineering design during a robotics project," *Contemporary Issues in Technology and Teacher Education,* vol. 22, no. 1, pp. 4-104, 2022.

[3]. D. H. Jonassen, "Toward a design theory of problem-solving," *Educational Technology Research and Development,* vol. 48. no. 4, pp. 43-85, 2000.

[4]. M. E. Jordan, and R. R. McDaniel Jr, "Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity," *Journal of the Learning Sciences*, vol. 23, no. 4, pp. 490-536, 2014.

[5]. T. T. Yuen, M. Boecking,, J. Stone, E. P. Tiger, A. Gomez, and A. Arreguin, "Group tasks, activities, dynamics, and interactions in collaborative robotics projects with elementary and middle school children," *Journal of STEM Education*, vol.15, no. 1, pp. 39-45, 2014.

[6]. B. M. Capobianco, H. A. Diefes-dux, I. Mena, and J. Weller, "What is an engineer? Implications of elementary school student conceptions for engineering education," *Journal of Engineering Education,* vol. 100, no. 2, p. 304-328, 2011.

[7]. S. Y. Yoon, M. Dyehouse, A. M. Lucietto, H. A. Diefes-Dux, and B. M. Capobianco, "The effects of integrated science, technology, and engineering education on elementary students' knowledge and identity development," *School Science and Mathematics,* vol. 114, no. 8, pp. 380-391, 2014.

[8]. A. E. Adams, B. G. Miller, M. Saul, and J. Pegg," Supporting elementary preservice teachers to teach STEM through place-based teaching and learning experiences, *Electronic Journal of Science Education,* vol. 18, no. 5, 2014, Retrieved from https://files.eric.ed.gov/fulltext/EJ1188278.pdf

[9]. C. E. Hmelo-Silver and H. S. Barrows, "Goals and strategies of a problem-based learning facilitator," *Interdisciplinary Journal of Problem-Based Learning,* vol 1, no. 1. 2006.

[10]. A. P. Rehmat, and K. Hartley, "Building engineering awareness: Problem-based learning approach for STEM integration," *Interdisciplinary Journal of Problem-Based Learning,* vol. 14, no. 1., 2020.

[11]. A. P. Rehmat, K. Glazewski, and C. E. Hmelo-Silver, "*Contextualizing problem-based learning: An overview of research and practice*", The Handbook of Educational Psychology, The Oxford Press, 2022.

[12]. W. H. Gijselaers, "*Connecting problem-based practices with educational theory. Bringing problem-based learning to higher education*," San Francisco, EUA: Jossey-Bass Publishers, 1996. doi.org/10.1002/tl.37219966805.

[13]. K. Farnsworth, and J. S Larson, "Problem-based learning in K-12 engineering lessons: Supporting and scaffolding student learning. In *2020 ASEE Virtual Annual Conference Content Access*, 2020, June.

[14]. D. R. Brodeur, P. W. Young, and K. B. Blair, "Problem-based learning in aerospace engineering education," *In Proceedings of the 2002 American society for engineering education annual conference and exposition,* Montreal, Canada, 2002.

[15]. U. Sarı, M. Alıcı, and Ö. F, Şen, “The effect of STEM instruction on attitude, career perception and career interest in a problem-based learning environment and student opinions,” *The Electronic Journal for Research in Science & Mathematics Education*, vol. 22, no. 1, 2018.
[16]. Z. Zacharia, and A. C. Barton, “Urban middle-school students' attitudes toward a defined science. *Science Education*,” vol. 88, no. 2, pp.197-222 2004.
[17]. C. Papanastasiou, and E. C. Papanastasiou. “Major influences on attitudes toward science,” *Educational Research and Evaluation*, vol. 10, no. 3, pp. 239-257, 2004.
[18]. A. Unfried, M. Faber, D. S. Stanhope, and E. Wiebe, “The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM),” *Journal of Psychoeducational Assessment*, vol 33, no. 7, pp. 622-639, 2015, doi.org/10.1177/0734282915571160.
[19]. Y. H. Ching, D. Yang, S. Wang, et al., “Elementary School Student Development of STEM attitudes and perceived learning in a STEM integrated robotics curriculum,” *TechTrends*, vol. 63, pp. 590–601, 2019, doi.org/10.1007/s11528-019-00388-0.
[20]. L. Sun, L. Hu, W. Yang, D. Zhou, X. Wang, “STEM learning attitude predicts computational thinking skills among primary school students,” *Journal of Computer Assisted Learning*, vol. 37, no. 2, pp. 346-358, 2021.
[21]. S. Brophy, S. Klein, M. Portsmore, and C. Rogers, “Advancing engineering education in P-12 classrooms,” *Journal of Engineering Education*, vol. 97, no. 3, pp. 369-387, 2008.
[22]. J. Chiu, A. Gonczi, X. Fu, and M. D. Burghardt, “Supporting informed Engineering design across formal and informal contexts with WIS Engineering,” *International Journal of Engineering Education*, vol. 33, no. 1, pp. 371-381, 2017.
[23]. N. DeJarnette, “America's children: Providing early exposure to STEM (science, technology, engineering, and math) initiatives, *Education*, vol 133, no. 1, pp. 77-84, 2012.
[24]. C. P. Lachapelle and C. M. Cunningham, “Engineering in elementary schools. Engineering in pre-college settings: Synthesizing research,” *Policy, and Practices*, pp. 61-88, 2014.
[25]. C. M. Cunningham, and C. P. Lachapelle, “The impact of Engineering is Elementary (EiE) on students’ attitudes toward engineering, and science,” *Presented at the 117th ASEE Annual Conference & Exposition*, Louisville, KY, 2010.
[26]. L. D. English and D. T. King, “STEM learning through engineering design: Fourth-grade students’ investigations in aerospace,” *International Journal of Stem Education*, vol. 2, pp. 1-18, 2015.
[27]. K. C. Powell and C. J. Kalina, “Cognitive and social constructivism: Developing tools for an effective classroom,” *Education*, vol. 130, no. 2, pp. 241-250, 2009.
[28]. C, M. Seimears, E. Graves, M. G. Schroyer, and J. Staver, “How constructivist-based teaching influences students learning science,” *Educational Forum*, vol. 76, vol. 2, pp. 265-271, 2012.
[29]. J. Watson, “Social constructivism in the classroom,” *Support for Learning*, vol. 16, no. 3, pp. 140-147, 2001.
[30]. L. S. Vygotsky, “*Mind and society: The development of higher mental processes*,” Cambridge, MA: Harvard University Press, 1978.
[31]. E. Hmelo-Silver, “Problem-based learning: What and how do students learn?,” *Educational Psychology Review*, vol. 16, no. 3, pp.235-266, 2004.

[32]. L. Liu, J. A. Mynderse, A. L. Gerhart, and S. Arslan, "Fostering the entrepreneurial mindset in the junior and senior mechanical engineer curriculum with multi-course problem-based learning experience," *In Proc. FIE 2015: The 45th Annual Frontiers in Education (FIE) Conference*, pp. 1-5,.2015.

[33]. J. W. Creswell, And W. Zhang, "The application of mixed methods designs to trauma research," *Journal of Traumatic Stress: Official Publication of the International Society for Traumatic Stress Studies*, vol. 22, no. 6, pp. 612-621, 2009.

[34]. L. Tarhan, H. Ayar-Kayali, R. O. Urek, and B. Acar, "Problem-based learning in 9th grade chemistry class: 'Intermolecular forces'," *Research in Science Education*, vol. 38, no. 3, pp. 285-300, p. 2008.

[35]. S. B. Merriam, "*Qualitative research: A guide to design and implementation*," San Francisco, CA: Jossey-Bass, 2009.

[36]. S. Purzer, T. J. Moore, D. Baker, and L. Berland, "Supporting the implementation of NGSS through research: engineering," In *NARST Annual International Conference,* 2014.