From Carnival Games to Plastic Filters: Preparing Elementary Preservice Teachers to Teach Engineering

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Abstract: Preservice teachers (PSTs) in an educational foundations course were tasked with leading elementary students in an engineering design challenge. To explore different approaches for helping the PSTs develop competence in engineering education, two implementation methods were tested. In Spring 2022, PSTs collaborated with undergraduate engineering students to develop carnival-themed design challenge lessons. In Fall 2022, PSTs worked with their PST classmates to teach a professionally prepared engineering lesson focused on designing plastic filters. PSTs' knowledge of engineering and engineering pedagogy were compared across the two semesters using an exploratory approach. Both groups showed increases in engineering knowledge and engineering pedagogical knowledge. Item-level differences suggest unique benefits to each approach providing insight for teacher educators designing interventions to prepare PSTs to integrate engineering into elementary education.

Keywords: P-12 engineering, elementary engineering, engineering design process, engineering pedagogical content knowledge, preservice teacher preparation

Introduction

Research indicates that engaging elementary students in engineering can increase their technological literacy which our society increasingly depends on to solve major societal and environmental challenges (Lachapelle & Cunningham, 2014; NGSS, 2013). When children craft a prototype as a solution to an engineering design challenge, they are engaging in making (Rodriguez et al., 2018; Marshall & Harron, 2018), a practice that involves "creatively designing and building material objects for both playful and useful ends" (Martin, 2015, p. 1). Making and engineering offer students agency and cultivate 21st century skills, such as creativity, collaboration, and problem solving (Taylor, 2016), and have shown benefits in student engagement, self-efficacy, and interest in STEM (Papavlasopoulou et al., 2017).

Recent curricular efforts call for children to be introduced to engineering at an early age (NGSS, 2013). However, current literature highlights that few elementary preservice teachers (PSTs) are exposed to engineering as part of their P-12 schooling or professional teacher preparation (Hammack & Ivey, 2017). As a result, elementary teachers often feel unprepared to integrate engineering into their instruction (Rose et al., 2017). Thus, teacher preparation programs need to help PSTs gain basic knowledge of engineering practices and pedagogy so they can effectively integrate engineering into their future instruction.

Preservice teachers in an educational foundations course at a mid-Atlantic university were introduced to engineering and tasked with leading elementary students in an engineering design challenge. To explore different strategies for helping the PSTs develop competence in engineering education, two implementation methods were tested. In Spring 2022, PSTs collaborated with undergraduate engineering students (UESs) to develop carnival-themed design challenge lessons. In Fall 2022, PSTs worked with their PST classmates to teach a professionally prepared engineering lesson focused on designing plastic filters. PSTs' knowledge of engineering and engineering pedagogy were compared across the two semesters. The goal was to explore the influence of the two implementations on PSTs' knowledge related to teaching engineering and to provide insight on approaches teacher educators can use to prepare PSTs to integrate engineering into elementary education.

Conceptual Framework & Literature Review

Preparing teachers to integrate engineering requires the development of basic domain knowledge, relevant pedagogical knowledge, and the intersection of the two, often referred to as Pedagogical Content Knowledge (PCK) (Brophy et al., 2008; Shulman, 1986). PCK is the knowledge that connects a teacher's cognitive understanding of the subject matter content with the knowledge of how to teach that content effectively (Shulman, 1986). In the case of teaching engineering at the elementary level, there is agreement that the relevant content knowledge does not typically involve mastery of engineering facts, concepts, or theory but rather should focus on the hands-on application of the engineering design process (LaChapelle & Cunningham, 2014) as an approach to solving problems using math and science concepts along with a general understanding of the discipline and its practice (Cunningham & Carlsen, 2014; Pazos et al., 2023). Shulman's model has been expanded to include intersections with domain-specific knowledge and broader pedagogical knowledge, such as the ability to use educational technology to enhance teaching and learning (i.e. Technological Pedagogical Content Knowledge (Mishra & Koehler, 2006)). Engineering Pedagogical Content Knowledge (EPCK) then refers to knowledge of pedagogical methods for supporting children's engagement in the engineering design process which includes defining a problem; brainstorming, planning, creating a solution; testing the solution and making improvements based on the results; and sharing findings with others (Lachapelle & Cunningham, 2014). EPCK requires knowledge of how to guide students through this process as well as an understanding of how to identify appropriate design challenges and support students in other engineering practices, such as the ability to work in teams and preserve through failure (Cunningham & Carlsen, 2014).

Literature on engineering pedagogical content knowledge is limited (Love & Hughes, 2022); however, related literature does suggest that there is a "strong connection between preparation experiences and educators' pedagogical content knowledge" (p. 5). Martin and Ritz (2014) identified PCK as a high-priority area of engineering educational research. Teacher preparation programs should concentrate both on the infusion of engineering content knowledge and engineering pedagogical knowledge, and on providing a greater number of "significant preparation experiences" (Love & Hughes, 2022, p. 16) to increase teachers' proficiencies in teaching engineering content and practices. This aligns with work by Sun and Strobel (2014) who found that teaching engineering in real classrooms in school settings was essential for teachers to construct their EPCK. Several studies have found that developing and teaching engineering lessons through engineering design challenges improved PSTs' knowledge of engineering practices (Cima et al., 2022; Fogg-Rogers et al., 2017; Gutierrez et al., 2022; Lewis et al., 2021).

Providing PSTs with practical experiences teaching engineering encourages them to take risks and "learn through experiencing the discomfort of being less certain about what is (or might be) happening" (Nilsson & Loughran, 2012, p. 719). Teacher preparation programs play an important role in challenging PSTs to engage in authentic pedagogical tasks (e.g., lesson planning, direct instruction), particularly in content areas in which they may not be as comfortable or familiar with (i.e., engineering knowledge and practices). The current study examines the changes in PSTs' knowledge of engineering practices and pedagogy following lesson preparation and implementation with elementary students. Specifically, it asks: *What are the differences in PSTs' knowledge of engineering practices and knowledge of engineering pedagogy following two implementation models of teaching engineering lessons to elementary school students? What do these differences suggest about the approaches used to prepare teachers to integrate engineering into elementary education?*

Methods

The engineering education intervention was implemented under different conditions over the course of two semesters as part of an introductory course for preservice teachers. In both conditions (Spring 2022, n=10 and Fall 2022, n=17), the PSTs prepared for and taught an engineering lesson with an engineering design challenge to fourth grade students. The study was approved by the University's institutional review board and participants signed media release forms.

In Spring 2022, PSTs and first year engineering students collaborated in cross-disciplinary teams to lead fourth graders in carnival-related engineering design challenges. Team evaluation software, the Comprehensive Assessment of Team Member Effectiveness (CATME) (Loughry et al., 2014), was utilized to place education and engineering students with compatible schedules and heterogeneous GPAs into teams of four to five students. Although the engineering and education students were enrolled in separate courses, the courses were held concurrently, and the two instructors brought their classes together for three collaborative class sessions. During these sessions, the teams completed an engineering design challenge, engaged as students in the specific design challenge they planned to teach, and practiced teaching their lesson to a group of peers. Teams also met outside of class three times to create a team charter, draft their lesson, and finalize their lesson following feedback.

The carnival theme was selected because COVID-19 restrictions were still in place and the lessons would be taught outdoors. The teams were given the choice of three engineering design challenges that simulated outdoor carnival attractions: a claw, a paddle-powered boat, or a kicking machine. The instructors modified existing instructional materials to create a one-page guide for each challenge with suggested supplies, vocabulary, and tips. The engineering students were tasked with designing and building a "testing station" which the children would use to test their claw, boat, or kicking machine (see Figure 1). Following this construction, teams moved through their design challenge and piloted their testing stations during a collaborative class session. After this initial test, teams redesigned their testing stations as needed and drafted a lesson plan to lead a group of fourth graders through their chosen challenge. The plan required a number of elements, including: learning targets; safety considerations; lesson logistics/roles; an ice-breaker to learn the children's names; an introduction to engineering, the engineering design process (EDP), and their topic; guiding questions to lead the children through the EDP; and a written review quiz aligned with their learning targets. To rehearse, each team taught their lesson to a group of peers and received feedback on their performance and lesson plan. After reviewing their feedback and making final revisions, fourteen cross-disciplinary teams delivered 75-minute lessons at two participating schools.

Paddle-powered boats | Mechanical Claw | Kicking Machine

Figure 1. Carnival-themed engineering design challenges incorporating testing stations designed by first-year engineering students during Spring 2022

In Fall 2022, PSTs worked with their education classmates to teach a plastic filter design lesson for fourth graders who would visit the university campus. As in Spring, the teams were formed with CATME and the PSTs prepared for the lesson through in-class and out of class meetings. Besides the team composition, there were two other major differences between the semester implementations: location/format and topic. Whereas the lessons were taught outside local schools in Spring, in Fall, the lessons were taught inside university classrooms with a multimedia slideshow to guide their lessons. This slideshow was created by the instructor with the PSTs required to add certain elements: a strategy to learn the children's names, learning targets, safety rules, and multiple-choice review questions. The PSTs also needed to determine team member roles, such as who would present which slides, who would distribute which materials, etc. Accordingly, the PSTs focused mainly on how they were going to distribute the work of teaching the lesson rather than on developing the content they were going to teach. The second major difference was the lesson topic. The Fall lesson was adapted from a Youth Engineering Solutions (YES) unit where "Students consider the effects of plastics on the marine ecosystem and community as they engineer filters to reduce plastic waste entering the ocean" (YES, 2023). It was selected because of its close alignment with the fourth grade Virginia Science Standards of Learning and because it was determined that the PSTs, who were in their first education course, would be more likely to be successful teaching on their own with a pre-made lesson rather than trying to develop a lesson with just a brief outline (as was done in the spring implementation). The original YES unit was designed for implementation over seven lessons and thus had to be adapted for a shorter timeframe. The course instructor reduced it to two lessons: a pre-lesson that she taught to the fourth graders a day ahead of the main lesson to introduce the effects of plastic pollution on ocean ecosystems, and the 105-minute lesson taught by the PSTs that engaged the children in the EDP to design, build, and test a filter that would catch plastics pollutants as they exited a model river and flowed into a model bay (see Figure 2).

Children testing their filter in a model bay A PST utilizing the instructor-made slideshow

Figure 2. In Fall 2022, fourth graders designed plastic filters using a lesson adapted from Youth Engineering Solutions (YES)

This study was limited by small sample sizes and thus the analysis is best defined as exploratory. It uses quantitative analysis to compare PSTs' engineering knowledge and engineering pedagogical content knowledge between the two semesters using six measures. There were two types of instruments: self-report surveys that assessed PSTs' *perceptions* of their knowledge and multiple-choice tests that directly assessed PSTs' engineering-related knowledge. Three subscales from a previously validated survey instrument (Pazos et al., 2023) were used to assess PSTs' perceptions of their knowledge related to teaching, *Pedagogical Content Knowledge (PCK)*; teaching engineering, *Engineering Pedagogical Content Knowledge (EPCK)*; and engineering practices, *Knowledge of Engineering Practices (KEP)*. The subscales utilize a five-point Likert scale (1=strongly disagree, 5=strongly agree) and contain seven, seven, and nine items respectively. Three instruments were used to directly assess PSTs' knowledge related to engineering and teaching engineering. PSTs' knowledge of what engineers do during the design process, or *Design Process Knowledge (DPK)*, was measured using 24 multiple-choice questions adapted for elementary school teachers (Nadelson, 2015). The authors developed a 15-item multiple-choice *Assessment of Engineering Knowledge (AEK)* to align with the knowledge-based objectives of the project: (a) define engineering and name several subfields, (b) describe the EDP, and (c) explain basic math and science concepts connected to common engineering design problems. Finally, a six-item multiple-choice *Engineering Pedagogical Knowledge Test (EPKT)* was developed by the authors to align with key features of engineering instruction, including engaging students in the EDP, facilitating student inquiry, and developing appropriate design challenges. In summary, three measures related to PSTs' knowledge of engineering and three related to PSTs' knowledge of pedagogy; likewise, three measures assessed PSTs' perceptions of their knowledge and three measures directly assessed their knowledge.

Results

Two inferential statistical analyses were conducted, the first looking at changes over time within each of the two conditions, and the second, comparing the two conditions across all measures. The first analysis addresses the question of whether changes were observed in the variables of interest within each condition. A paired t-test was used for each measure to determine whether the means of the pre-test and post-test scores were statistically different for each group of PSTs. Differences were determined based on a significance level of p-value < 0.05. The second analysis utilized Analysis of Covariance (ANCOVA) to look for differences between the Fall and Spring groups across each measure. The pre-test scores were used as control variables to account for potential pre-existing differences. While standard parametric analyses were used, it is important to note that the sample sizes were small and the data did not meet all assumptions (e.g. normality) for this type of analysis. Consequently, results should be interpreted cautiously.

There was a significant increase between the pre and post values for all three self-assessment measures for both the Fall and Spring groups indicating an overall gain in PSTs' assessment of their understanding. Both groups self-reported an increase in knowledge after the completion of the project. For the knowledge tests, there were significant pre-post increases in *Design Process Knowledge* for both groups and a significant pre-post increase on the test assessing engineering pedagogical knowledge for the Fall group. Results are summarized in Table 1 for PSTs' self-assessment surveys and in Table 2 for the multiple-choice knowledge tests. There were no significant differences between the two groups on any of the measures when controlling for pre-test values suggesting similar levels of overall understanding of engineering knowledge and engineering pedagogical knowledge in both groups. Between-group results are summarized in Table 3.

As mentioned above, the small samples violated some assumptions for the parametric analyses conducted. Furthermore, while the perceptions survey was validated, the three instruments used to directly assess PSTs' knowledge were not validated, nor were they designed to measure distinct constructs within the domains of engineering knowledge or engineering pedagogical knowledge. Accordingly, the results should be interpreted cautiously and considered formatively by teacher educators as they plan activities to prepare elementary PSTs to teach engineering.

Table 1. Paired T-test Results for PSTs' Perceived Knowledge

		Fall 2022 (YES lesson no UES)					**Spring 2022 (Carnival lesson with UES)**				
		n	Mean	SD	t-test: t	t-test: p-value	n	Mean	SD	t-test: t	t-test: p-value
PCK	pre-test	10	3.70	0.43	3.16	0.01*	16	3.55	0.79	4.79	0.00*
	post-test		4.40	0.59				4.42	0.55		
EPCK	pre-test	10	2.30	0.93	5.28	0.00*	16	2.74	1.10	5.56	0.00*
	post-test		4.46	0.60				4.42	0.55		
KEP	pre-test	10	3.16	0.80	4.71	0.00*	16	3.15	1.11	5.21	0.00*
	post-test		4.46	0.47				4.47	0.48		

Notes. ns=no significant differences between groups; *p-value < 0.05.

Table 2. Paired T-test Results for the Multiple-Choice Knowledge Tests

		Fall 2022 (YES lesson no UES)					**Spring 2022 (Carnival lesson w/ UES)**				
		n	Mean	SD	t-test: t	t-test: p-value	n	Mean	SD	t-test: t	t-test: p-value
DPK	pre-test	8	9.62	4.14	2.61	0.03*	14	8.64	5.34	4.90	0.00*
	post-test		14.2	4.40				13.3	3.05		
AEK	pre-test	9	10.40	3.97	1.73	0.122	14	9.43	5.03	1.09	0.294
	post-test		12.0	1.66				10.30	3.36		
EPKT	pre-test	9	2.44	1.13	3.83	0.00*	17	2.76	1.44	0.39	ns
	post-test		3.89	1.36				2.94	1.71		

Notes. ns=no significant differences between groups; *p-value < 0.05.

Table 3. ANCOVA Results by Variable

	Fall 2022 (YES lesson no UES)			**Spring 2022 (Carnival lesson w/UES)**			ANCOVA test	
	n	Adj. Mean	SE	n	Adj. Mean	SE	F	p-value
PCK	10	4.37	0.17	16	4.44	0.13	0.085	0.77
EPCK	10	4.44	0.18	16	4.43	0.14	0.002	0.96
KEP	10	4.46	0.14	16	4.47	0.11	0.009	0.92
DPK	8	14	1.07	14	13.4	0.80	0.172	0.68
AEK	9	11.7	0.55	14	10.5	0.44	2.84	0.10
EPKT	9	3.99	0.50	17	2.89	0.36	3.067	0.09

Notes. PCK pre grand mean = 3.61; EPCK pre grand mean= 2.57; KEA pre grand mean= 3.15; DPK pre grand mean= 9; AEK pre grand mean = 9.83; EPKT pre grand mean= 2.65.

Discussion & Exploratory Item-Level Analysis

The purpose of the study was to compare two approaches to preparing PSTs to teach engineering to offer insight that may be helpful to teacher educators planning engineering-related activities for their PSTs. Accordingly, an examination of individual items was done to provide a granular and nuanced look at PSTs' understanding of engineering and engineering pedagogy. As such, pre and posttest means on individual items were reviewed to look for topics where: both groups scored high (> 90% correct or > 4.0) or showed strong gains (> 25% or +1.0); both groups scored low (< 60% or < 3.0) or showed decreases (> 20% or -1.0); or there were notable differences in the groups' performance (> 25% in posttest means or > 25% difference in gainscores) that may suggest different levels of understanding. The next section includes a discussion of the inferential test results reported above integrated with this exploratory item-level analysis in order to relate the PSTs' performance back to the design of the implementations. The PSTs' performance is discussed for each of the two variables: engineering knowledge and engineering pedagogical knowledge. Within these discussions, the PSTs' holistic performance on the measures is discussed first followed by the groups' performance on selected individual items. As noted earlier, interpretations related to these comparisons should be considered speculative given the small sample size of the groups.

Engineering Knowledge

Three instruments were used to assess PSTs' knowledge of engineering. One focused on PSTs' self-reported assessment of their knowledge of engineering practices, while the other two were direct tests of engineering knowledge, one that assessed design process knowledge, and one that focused on the knowledge objectives of the project. There were no significant differences between the groups in PSTs' perceptions of their *Knowledge of Engineering Practices*, but there were significant pre-post differences within each condition. Both groups showed increases (0.5 - 1.8 points) suggesting the PSTs believed they learned engineering content knowledge over the course of the project. With the exception of familiarity with different fields of engineering which had a mean just below 4.0, post-test means were high (most 4.5 and above), indicating PSTs believed they had a good understanding of engineering practices. The highest means for both groups related to constraints and brainstorming, two concepts covered extensively in the implementations.

PSTs from both semesters showed increases in design process knowledge, averaging about 4 more questions correct at the post-test. While these within group differences were significant, there were no significant differences between the groups in overall score. However, group differences on individual test items across the two engineering knowledge tests seem to correspond to differences in the implementation design. First, based on their answers to related test items, PSTs in the Fall were more likely than their Spring peers to see the design process as a linear, step-by-step process, similar to a recipe, as opposed to cyclical and iterative. This difference in understanding of the EDP could be a result of the difference in the nature and structure of the design challenges implemented in each semester. The Fall lesson, adapted from YES, included a poster of the EDP with an arrow that PSTs moved to indicate the phase of the EDP currently being discussed. Although the poster shows the EDP as circular, the methodical moving of the arrow from one phase to the next may have reinforced the notion of a linear pathway. Second, Fall PSTs were more likely to correctly answer questions that recognized engineers' responsibility to focus on client needs at the start of and all throughout a project. This responsibility was demonstrated in the Fall lesson when the children role-played a variety of stakeholders concerned about plastic pollution. Interestingly, both groups scored low on a related question, "At the beginning of a project, excellent designers devote most time to defining the problem," suggesting that PSTs may need more help understanding what problem definition entails and why it is important. Finally, some between group differences were related to specific science concepts. Spring PSTs performed better than their Fall peers on items assessing their understanding of thrust and potential energy, concepts connected to their carnival-themed challenges. There was no discussion of these concepts in the Fall lesson on plastic filters. This introduces the idea that engineering design challenges could be purposefully selected to help reinforce specific science concepts.

The item-level analysis revealed strong increases in engineering knowledge across both groups on several specific topics. PST responses indicated gains in their understanding of what constitutes an engineering design task, the iterative nature of the engineering design process, and the presence of multiple valid solutions to engineering problems. Low scores on some items across both groups highlight areas where PSTs lacked understanding of engineering. Neither group of PSTs understood that manufacturing a final product is not necessarily part of the design process, nor did they realize that mechanical components are typically tested to failure. More than 50% failed to recognize that an engineer's next step after meeting design criteria is to communicate results to stakeholders. This result was somewhat surprising, especially for the Fall group, as their lesson specifically included a phase for sharing results. However, this phase came at the end of the lesson, and may have been skipped or rushed through.

PSTs' performance on another item may also be a result of time constraints within the lessons. Rather than responding that a child should draw a plan of their idea after identifying promising materials, PSTs in both groups were more likely to say the child should move directly to building and testing. In the execution of their lessons with elementary students--often in response to children's excitement to get started and pressure to finish the lesson in the allotted time--many teams moved quickly through the plan phase of the EDP. This tendency for PSTs to have children move quickly from brainstorming to creating, rather than carefully planning out a design based on their understanding of science concepts, such as material properties, could help explain why more PSTs indicated than engineering was largely a process of trial and error at the post-test than they did at the pre-test. If PSTs do not help children connect their design decisions to underlying STEM principles, either initially or during the redesign phase, engineering can seem like a process based mainly on trial and error. This undergirds the importance of planning engineering lessons with adequate time for children to explore materials, and to engage in both the plan and improve phases of the EDP.

Pedagogical & Engineering Pedagogical Content Knowledge

Three instruments were used to assess PSTs' knowledge of engineering pedagogy. Two were self-report measures: one focused on pedagogy broadly and one focused on engineering-specific pedagogy, and one was a multiple-choice test of engineering-specific pedagogy. There were no differences between the groups in PSTs' perceptions of their pedagogical content knowledge. There were, however, statistically significant differences between pre and post test scores in both conditions with high post-test means (> 4.0) suggesting that PSTs felt confident in their general pedagogical knowledge at the end of the project. Some of the highest gains (~1.2 points) were seen in the question "I know specific strategies to guide rather than lecture students" indicating that PSTs gained familiarity with active learning strategies critical for teaching engineering.

There were no significant differences between the groups in perceptions of engineering-specific pedagogical knowledge, but there were significant and quite large (1.4 - 2.5 points) pre-post differences within each condition suggesting the PSTs believed they learned a great deal about teaching engineering, such as how to introduce the EDP to students, during the project. Furthermore, post-test means were high (> 4.25), indicating PSTs believed they had a good understanding of engineering pedagogy at the project's end.

The test of engineering pedagogical knowledge painted a slightly different picture. There were significant pre-post differences for the Fall group but not for the Spring group, however the difference in mean scores between the two groups was not significant. This suggests that the Fall group gained knowledge of how to teach engineering, while the influence of the project on the Spring group is less clear. An examination of individual items highlights a concern. Both groups had trouble recognizing that a step-by-step set of instructions from a website would not be a good example of an engineering design challenge for children. Presumably several PSTs were unaware that the prescribed activity did not require children to make design choices and therefore would not constitute a design problem. This suggests PSTs may need to engage in discussions of what constitutes engineering. Furthermore, a trend seen in the knowledge test suggesting different levels of understanding between the groups was also observed in the pedagogy test. Fall PSTs did better than their spring counterparts on questions related to the importance of interacting with clients during the design process, suggesting they may have gained more knowledge on the responsibility engineers have to meet clients' needs and how to integrate that responsibility into the design process.

The differences in the PSTs' performance on these assessments may be connected to the design of the project in each semester and the structure of the lessons they taught. Fall PSTs followed a professionally prepared, highly structured engineering lesson which led fourth graders through well-articulated phases of the EDP, including a materials testing phase and a prolonged problem definition phase where the children role-played the part of various stakeholders to fully understand the problem of plastic pollutants in a bay. In contrast, Spring PSTs collaborated with their engineering partners to develop their lessons. They devised activities and guiding questions to lead the children through the EDP based on a brief handout outlining their design challenge. They also participated in a design activity connected to their lesson development by providing feedback as their engineering teammates iteratively designed testing stations for the children to evaluate their designs. The carnival-focused design challenges focused on physical science principles (e.g., utilizing potential energy from a twisted rubber band) rather than a societal issue (e.g., plastic pollutants in waterways) and thus did not require the children to consider the needs of multiple stakeholders. Finally, the Spring lessons were taught outside, without multimedia presentations, and as they were intended to simulate carnival games, tended to be less regimented. These contextual differences may have influenced the PSTs' understanding of the design process and how to guide children through it. The highly structured Fall lesson, in which PSTs moved an arrow on a poster depicting the EDP to show the phase in which the

the children were currently engaged, may have given PSTs the impression that engineering tends to (and should) proceed in a linear step-by-step fashion, whereas the more loosely structured Spring lessons may have presented a more flexible example of the engineering design process. Witnessing the engineering students iterate on the design of the testing stations used to evaluate the children's designs may have also reinforced the Spring PSTs' notion of engineering as an organic process that occurs over multiple trials. The Fall PSTs' inclination to suggest children to check in with a client before prototyping reflects the structure of their lesson in which the children considered the needs of multiple stakeholders through a role-playing activity prior to designing their solutions. In contrast, the Spring lesson did not specify a client or stakeholders beyond the participating children, and thus did not emphasize this responsibility. However, the Spring PSTs acted as stakeholders in the design of the testing stations used in their lessons, but may not have conceived of their role as clients in this design process. Had the instructors emphasized this relationship, the Spring PSTs may have developed a greater understanding of the client role in the design process.

Implications & Conclusion

Teacher educators are confronting a new reality where they must prepare elementary preservice teachers to integrate engineering into preK-6 instruction. Little research exists on how best to accomplish this. This study presents two different models for doing so, both of which include PSTs teaching engineering lessons to fourth graders. Self-report surveys and knowledge tests were used to examine the influence of the models on PSTs' knowledge of engineering and knowledge of engineering pedagogy. Results showed positive effects on PST knowledge and perceptions of knowledge for both models, suggesting that engaging PST in teaching engineering lessons to elementary students is a beneficial approach to preparing PSTs to teach engineering. An exploratory analysis comparing the responses of PSTs on individual items was done to provide additional insight into the two different approaches on PST learning. While these findings should be interpreted cautiously, they seem to suggest the different models may have reinforced different knowledge and understandings related to the engineering design process. PSTs who taught a highly structured and professionally prepared lesson on plastic filters were better able to answer questions about the EDP and more likely to understand the importance of meeting a client's needs but were also more vulnerable to the misconception that engineering is a linear step-by-step process. In contrast, PSTs who worked alongside engineering students and contributed meaningfully to the development of their lesson, were more likely to recognize the iterative nature of the design process and were better able to answer questions related to underlying STEM concepts reflected in their design challenges. Further research on this project will include an analysis of PSTs' written reflections which should add insight into the PSTs' perceptions of what they learned, and how their interactions with their teammates, either education students or engineering students, influenced their learning. As the authors move forward in their preparation of PSTs to teach engineering, they plan to continue to utilize professionally prepared lessons, especially for PSTs in their first education course, who may not be prepared to design their own lessons. They anticipate engaging students in a discussion of what constitutes engineering to reinforce the notion that design challenges must require children to make design choices. They also plan to be more mindful of the need to present the EDP as an iterative process that should involve stakeholders at multiple points, and to ensure that engineering lessons designate adequate time for children to plan, evaluate, and redesign solutions based on related STEM principles.

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