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Preschool Teachers Learn to Teach the Engineering Design Process (Research-to-Practice)

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Abstract

Nationally, engineering has been in the spotlight since the advent of the Next Generation Science Standards, which includes a focus on engineering practices and engineering-specific standards. Locally, our state added pre-kindergarten to our NGSS-aligned standards. The new expectations for learning engineering has put pressure on teachers to include engineering as part of their curricula. Teaching engineering involves a different way of approaching curricula than what many teachers are used to, with its focus on open-ended, multi-answer problems. Few to no preschool teachers have a background in engineering, yet many believe engineering is important to teach young children. The four preschool teachers in this study had a beginning knowledge of and positive attitudes toward teaching engineering. Block play and building structures like bridges and ramps, a natural beginning to engineering thinking as children construct, test the limits of, revise, and rebuild their structures, was a common occurrence in this preschool. For teachers who are beginning to learn about and implement the engineering design process (EDP), long-term projects that bring children though a full design process is ideal so the EDP is not overshadowed by children excited with short-term, hands-on activities. As such, the research question guiding this study was: How does preschool teachers' knowledge of and confidence with teaching the EDP evolve over the course of a long-term engineering project? The preschool teachers were guided by the researcher to explicitly include the EDP in a six-week project for children to redesign the outdoor play area while expanding their engineering curriculum to include tasks less familiar to the children. This was a qualitative research study using modified lesson study and participant observation. All planned lessons and related activities were video recorded, and teacher planning sessions were audio recorded. Data was analyzed using open and axial coding. Findings from this study showed that the preschool teachers' ability to plan for and implement specific components of the EDP improved over the course of the six-week study, moving from the researcher having to consistently remind the teachers of the EDP and the teachers unsure about how to include steps, to the teachers being able to plan for these on their own and with minimal prompting by the researcher. The teachers struggled more, although showed improvement, with their ability to connect to the EDP while teaching the children and be explicit with them about how they were engaging in the EDP. Implications include a consideration of how to help early childhood teachers who are novices with engineering explicitly plan for and include the EDP within long-term projects.

Introduction

Nationally, engineering is now in the spotlight with the recent adoption of the *Next Generation Science Standards*, or some adaptation of them, by many states. These new standards include a strong focus on science and engineering practices, and engineering-specific standards throughout all of K-12 [1]. Missing from NGSS, but present in many state learning standards as well as the national Head Start program's Early Learning Outcomes Framework [2], is preschool science and engineering. In the northeast United States, where this study took place, the states of Massachusetts, New York, Maine, Vermont, New Hampshire, Rhode Island, and Connecticut all have science and engineering standards for children in preschool. In general, the standards

recommend that children in preschool learn to identify and solve engineering-based problems. Many of the standards also recommend that children record their ideas and plans for engineering and science through simple drawings and writing. What is most important to note is that engineering is present in all of the standards documents for early childhood learning in these states.

While engineering education in the United States is in relative infancy, the available research so far "shows that engaging elementary and secondary students in learning engineering ideas and practices is not only possible, but can lead to positive learning outcomes" [3, pp. 149], such as improved math and science learning, gaining problem solving abilities, and an increased awareness of and interest in engineering as a career. At the early childhood level (defined as birth through age eight), there is a limited number of studies regarding engineering education. What these studies do point to is the "need for improving our understanding of what is entailed in the precursors of engineering thinking" [4, pp. 63] in early childhood education. Additionally, the Committee on K-12 Engineering Education notes that in all levels of education, little is known about "which engineering knowledge, skills, and habits of mind are most important, how they relate to and build on one another, and how and when (i.e., at what age) they should be introduced to students" [3, pp. 8]. Therefore, the Committee encourages research on engineering curricula "that will provide a basis for analyzing how design ideas and practices develop in students over time and [determine] the classroom conditions necessary to support this development" [3, pp. 7].

The new expectations of engineering learning standards in preK-12 education in the United States have put pressure on teachers to include engineering as part of their curricula. Learning to teach engineering involves a different way of approaching curricula than what many teachers are used to. As Brophy et al. [5] points out:

> when a teacher approaches teaching engineering design and what engineers do, the 'answer in the book' system breaks down. [S/He] has no list of correct answers (i.e. a design solution) because ill-structured and open-ended problems are designed to have multiple 'correct' answers. Teachers must become comfortable and proficient with the engineering process and learn to quickly recognize where learners are in the process…Many teachers lack the content knowledge and experience to make such an evaluation [5, pp. 381].

Few to no preschool teachers have a background in engineering, yet most believe engineering is important to be introduced and taught to young children [6]. As such, the research question guiding this study was: *How does preschool teachers' knowledge of and confidence with teaching the engineering design process (EDP) evolve over the course of a long-term engineering project?*

Background

Engineering Design Process

The engineering design process (EDP) is an iterative cycle of planning, designing, and creating that engineers undertake to solve real-world problems. There are several simple models of the

engineering design process that are useful for young children. These include the ask-imagine-plan-test-improve EDP developed by the Engineering is Elementary curricula for K-5 students [7], the think-design-create-test EDP used in a study with K-1 students [8], or the ask-imagine-try-try again used in a kindergarten class [9]. The EDP "as practiced by engineers is neither quickly learned by students nor easily taught by teachers" [3, pp. 57] as the design process can become overshadowed by students excited with short-term hands-on activities. Yet, there is limited knowledge on how young children engage with the EDP and on how teachers can best facilitate children's learning of it.

There are, though, some ways in which teachers have helped students learn to enact the EDP. Engineering notebooks, either written or digitally, may be used to provide structure to and scaffolds for the engineering design process and serve as a point of reference for students' decision making, discourse, and consensus [10], [11]. Fictional books where the characters are in need of a design process to solve a problem are a common way to jumpstart students' motivation to engage in engineering [7], [8], [12]. Combing engineering design with social studies, language arts, and mathematics may help increase engineering's appeal to a variety of students [13]. Design challenges, such as those provided by Science through LEGO Engineering [14] or PBS Design Squad [15] provide unique ways to inspire students to use the design process. Attending repeatedly to the physical testing of products in order to learn from failure and improve the design helps students gain a deeper understanding of the phenomenon [16]. Overall, according to Capobianco et al. [17], there is no universal approach to teaching the engineering design process in an elementary classroom. As such:

> Integrating the engineering design process is a complex activity that requires teachers to consider the resources they have available, knowledge necessary to understand and apply the design process, and understanding of how students can learn and engage in the engineering design process effectively and productively. [17, pp. 13]

Young Children's Understanding of Engineering

Children's early learning experiences, both positive and negative, have a cumulative effect on learning [18]. By the time students enter middle school, high school, and college, their ideas and attitudes toward engineering have been well-established [4]. One study found that children in first and second grade thought of engineers as mechanics and laborers, a low percent thought of engineers as technicians, and none thought of engineers as designers [19], [20]. "On a practical level, young people who believe engineers drive trains or repair car engines or who have negative stereotypes of the profession are unlikely ever to consider studying engineering or pursuing it as a career" [3, pp. 55]. Elementary students who have been exposed to engineering in school have an increased ability to see themselves as potential engineers [21]. Early childhood education is an opportune time to introduce positive experiences with engineering.

Young children are capable of participating in "developmental engineering," which means engaging young children in engineering thinking, and learning about the what, why, and how of human-made objects in ways that support young children's developmental needs and abilities [4]. For example, block play and building structures like bridges and ramps are common activities in early childhood settings and are a natural beginning to engineering thinking as children continually construct, test the limits of their designs, revise, and rebuild their structures

[22]. In a study with kindergarten English learners, during a five day engineering project, the students were able to use engineering design vocabulary and engage in discussion about engineering, as well as show affective and cognitive engagement throughout the project [23]. In a study of preschool children engaging in STEM activities, including engineering practices, they could retell ideas related to their STEM lessons, suggesting that these subject areas, including engineering, are developmentally appropriate for young children to engage in [24]. Other researchers found that kindergarten students are able to compare design solutions and point out the positive attributes of their designs, although may have trouble determining the cause for testing failures [25]. Given the curiosity and excitement that young children have for the world around them, it is important to capitalize on this and introduce them to science and engineering as young learners [26].

Teacher Understanding of Engineering

Most teachers have not experienced engineering, or participated in engineering pedagogical development, while learning to become a teacher [27]. As such, many are uninterested in obtaining further schooling in the STEM fields, particularly in engineering [28]. Even after participating in professional development for engineering, teachers do not always view themselves as teachers of engineering, but more often as "teachers of children" or teachers of subjects like reading and mathematics [29]. This may be because they have misconceptions about what engineers do or simply do not have enough experience with engineering teaching or learning. For example, in a study of 134 Mexican teachers who completed the Draw-An-Engineer test and follow up questions, over three quarters of their drawings depicted an engineer as someone who supervises others, while almost one quarter of the teachers depicted an engineer as someone who works on a construction site [30]. Other studies have found that teachers are somewhat knowledgeable about engineering as a problem-solving activity associated with progress, although struggle to differentiate between science and engineering [31]. For teachers to want to participate in engineering curriculum development and implementation, it is critical that they have a positive attitude toward engineering, intrinsic motivation to continue with a long-term project, and a desire to experiment with different ways of teaching and learning for students [32].

The teacher's role is crucial in directing students through the EDP by providing explicit guidance and developing activities for solving real-world problems [3]. Teachers who attend professional development for engineering may be more likely to change their hands-on activities from exclusively scientific investigations to a combination of engineering design and scientific investigations [33], [34], and show increasingly positive attitudes toward engineering, even after time [35]. They are also likely to significantly increase their knowledge of the EDP and sustain those knowledge gains beyond the end of the professional development they participated in [36]. Teachers struggle with teaching engineering though, even after participating in long-term professional development. For example, in learning to implement the EDP, teachers were found to have used it during lessons that were not necessarily engineering, such as designing and building scientific models [36]. Teachers may also emphasize some elements of an EDP, such as posing a problem, generating ideas, and building a product, over other elements, such as asking questions and defining the problem [36], [37]. Teachers may also perceive greater learning of interpersonal skills than technical content by their students when engaging in engineering, which

may cause them to teach it less often as the demands on their time to prepare students for learning STEM content in preparation for standardized tests can overtake their desire to include the EDP as part of their students' learning [38]. Contrary to this, the students in the classrooms of teachers with high fidelity of implementation of engineering design performed better on tests of science and engineering content than students in classrooms with teachers who were not enacting an engineering design process as well [39]. Some teachers perceive engineering as enabling deeper thinking by their students in science and other content areas, and helping students connect to engineering as a future career [40].

Early childhood teachers, being novices to engineering education themselves, have much to learn about integrating the EDP in developmentally and pedagogically appropriate ways to facilitate early engineering thinking [4]. Many early childhood teachers believe in the importance and appropriateness of teaching STEM to young children [41]. A survey of teachers and staff who worked at Head Start indicated that they had an overall interest in teaching engineering, but their interest was less than the parents of the children who attended, and the teachers also underestimated the parents' interest in the topic [42]. Unfortunately, preschool teachers often report that they feel unprepared to teach both science and engineering [43]. Similar to the study mentioned earlier, preschool teachers primarily associate engineering with building and construction, with their second association being planning and problem solving [42]. Yet, for those teachers who are already aware of the importance of teaching STEM in early childhood education, they are more likely to be ready to teach STEM to their students [41] when they are taught how to do so in developmentally appropriate ways that attend to the EDP.

Methods

This long-term engineering project took place over six weeks at a campus preschool. At the time of the study, the preschool hosted 20 children, ages 2.9 to 5 years, and four teachers. The overall goal of the six week engineering project was in designing a more beautiful and useable area for the part of the playground that was mostly empty at that time. The research study was approved by the campus IRB and sought permission from the parents of all children and the teachers for their involvement. The researcher was a participant observer and was at the preschool for all planned lessons and activities, went on the two field trips, and participated in the teachers' planning time. All planned lessons and activities were video recorded and later transcribed. These were not analyzed for the part of the study being reported here.

A modified form of lesson study was the method used to collect data from the teachers. Lesson study is where teachers work together to study curriculum and formulate long-term goals for student learning, write lesson plans, conduct the lessons, watch each other and collect data while the lesson is taking place, reflect on the lesson by sharing data and using it to illuminate student learning, and develop new goals for the next lesson [44]. The director of the preschool approved an extended planning time for the teachers to engage in lesson study. Each planning session lasted at least one hour, sometimes more. There were eight planning sessions with the teachers, all of which were audio recorded and later transcribed. It was modified lesson study because, due to the nature of teaching in a preschool, the teachers were not able to watch each other by only being observers of a lesson but were always active participants. Thus, data collection in-the-moment was informal and recorded on the video rather than collected in writing.

Methodology

The current study was a qualitative research study where the transcribed planning sessions were coded by the researcher to represent how the teachers were talking about the EDP, the children's learning, and planning for what to teach. The constructivist grounded theory approach was used to review the transcripts, beginning with open coding to find repeating themes, and then re-reviewing for a second, deeper analysis to decide on which themes were most prominent [45]. The transcripts of the planning sessions contained the most evidence for the two themes described below. The transcripts of the lessons with children have not been analyzed yet, so the findings described below are those that are only recurring within the planning sessions with the teachers. Future iterations of this work will be able to determine connections between the discourse of the planning sessions and that of teaching engineering to the preschool children. The researcher was a participant observer during the planning sessions [46], mostly listening but also asking questions to clarify what teachers were thinking and providing suggestions when the teachers seemed stuck or were veering off from the intended project goals.

The Setting and Engineering Project

The preschool teachers in this study had a beginning knowledge of and positive attitudes toward engineering. This was due to the fact that they had seen the researcher teach engineering lessons in the past to the preschool children, several of the teachers had attended engineering workshops, and the teachers had been implementing an engineering project about building structures (houses, bridges, and ramps) in the months leading up to when the study took place. However, what set the current study apart from the engineering practices at the preschool at that time was its intended interrogation of the teachers' understanding of the EDP and how that played out in lessons taught to the children. Anecdotal evidence by the researcher suggested that this was not a prominent feature of the engineering lessons the teachers had been implementing prior to this study. Thus, the teachers were asked to consciously include the EDP in the long-term project while expanding their engineering curriculum to include tasks the children were not as familiar with in an effort to help the children extend their ideas of what engineers do. Throughout the six-week engineering project, a variety of engineering lessons took place, including building an outdoor waterway, designing houses for the three little pigs, and drawing a playground and creating a model of it. The children also took field trips to Home Depot, a local zoo with an attractive play area for young children, and to the large town playground. A local male engineer who had designed the large town playground, along with many areas on the college campus, visited with the children three times to share his design process. Another female engineer visited one time to do a lesson with the children about drawing plans, focusing on their use of shapes to draw playground features. Overall, the main goal of the project was for the children to redesign a part of their playground area; as the project progressed this turned into designing a garden area for their playground with water that moved through it.

Findings

Finding #1: The preschool teachers' ability to plan for and implement some components of the EDP improved over the course of the six-week study.

Specifically:
1) At the beginning of the project, although they created their own EDP, the teachers rarely referenced it during teaching and mostly had the children build.
2) Midway through the project, the teachers began having the children do more planning during the lessons.
3) Near the end of the project, the teachers were thinking about how to best have the children test and share, while still having them plan.
4) The teachers struggled the most throughout the project with the ask and imagine steps of the EDP that they created.

Teacher-Created EDP

At the beginning of the study, the teachers were not familiar with the EDP. During the planning sessions before the project began with the children, the researcher brought in several examples of early childhood EDPs for the teachers to read about and consider. The teachers liked best the EDPs that were explicit about having students share their ideas. In the end, they created their own circular process with graphics that one of the teachers picked out. Figure 1 shows a picture of the final EDP that was presented to the children and referred to throughout the whole project.

Figure 1. The engineering design process that the preschool teachers created for their students.

One of the lessons near the beginning of the project was for the children to make their own circular EDP like the figure shows. They colored, cut, and glued the graphics on a cardboard circle, and then had a clothespin with an arrow that they could move around the circle to show which step of the EDP they were working on. The teachers acquired this idea after going to a STEM workshop at the beginning of the project: "one of the workshops we were at, they had a really big sort of cloth representation. We thought about a way to make a simple representation of those steps in the circle format with a clip, like a clothespin… do a picture and a word and have [the children] each make their own and call it an engineering tool."

Another teacher explained that, "We had talked about having one for the group to look at and then one for out here [in the other classroom], but we thought it might keep them focused more that we could all explore it together and say, 'Okay, where do we think we are now?' … That way they can keep track of the progress. So we'll have one within the classrooms and then we thought we could add one to the bulletin board so that they could show their parents like, 'This is what we're doing.' With index cards maybe explaining ... like ask would be at the top so we

could explain what the question for that day was for the parents. Then we'll talk about that question within the group times."

Despite the excitement about developing their own EDP and using it throughout the project, aside from the actual making of the cardboard EDP by each child, much of what the teachers wanted to do with it never came to fruition. One of the teachers did make her own larger cardboard EDP similar to the children to use during lessons, but the ideas of having the children keep track of their stage and showcasing that development to parents was never fulfilled. The teachers said how they wanted to include the EDP into what they were doing, explaining early on that the idea of making and using the cardboard EDP they created for the project was "to prompt [children] with those stages all week long. … I'm hoping at the end that … they'll be able to talk about what they did. We'll be able to say, 'Okay, what did you do first? What did you do next?' [and they'll] be able to tell us those steps in some manner. I'm hopeful that it will happen that way." However, soon after having the children make them, one teacher allowed the children to take home their EDP because they were excited by it. They never really had the opportunity to use it for its intended purpose. It seemed like the teachers had some difficulty thinking ahead to when and why it might have been useful to have the children keep their cardboard EDPs at the school through the duration of the project.

Project Beginning

During planning sessions at the beginning of the project, the researcher had to consistently remind the teachers of the EDP. The teachers were often unsure about how to include steps, particularly the beginning stages of imagine and plan. For example, the teachers were talking about the children building, and the researcher asked the teachers to consider if there was a way to have the children engage in the plan step of the EDP more directly prior to building. One teacher admitted "that definitely could have been a step that we had taken before going to the water table … Because I think they were kind of trying to plan while doing." That caused the teachers to wonder if they had "too many steps" in the EDP that they had created. They decided that they should continue to "get them into it, and excited, and engaged, and at least they're building, and they're testing right now… Try to keep that going, and then we'll add in more stuff," meaning additional steps of the EDP.

In planning for week 2, the teachers were comfortable with continuing to skip the plan step of the EDP. Eventually, the researcher brought up the idea that "maybe kind of a prelude [to planning], since you said they're not ready to actually sit and plan, but you could just have them stop for 30 seconds and say all right, think in your head." The teachers thought this would be a good way to help the children learn this step.

Project Midway

When planning for mid-project activities, which would include a trip to Home Depot and a second visit from a local engineer, the teachers talked a lot about prompting the children to ask more questions in both of these situations. They thought maybe they could write the children's questions down to have a record of them for future use. However, their rationale for this was to have something that the children could talk to the engineer about to make the most use of his

time, rather than attempting to specifically connect this process to one of the first steps of their EDP. In actuality, none of the question asking or recording of questions ended up taking place during the Home Depot trip or before the engineer's visit.

During week 4 the teachers were beginning to notice what parts of the EDP they were not attending to as well as others. At this point in the project they had the children drawing plans and trying to recreate those plans through models. But, they recognized that there was still more to their EDP than that: "We haven't talked at all though about how, okay, so now they have the model, do they want to modify it? We haven't done anything with testing or looking at the models." However, they struggled with determining how to have the children test the models they made, noting that "I don't know how you make that happen. Go from, okay this is a building, now we want to put it in, how do we make it work or something." The researcher suggested that the children could use an object to see if it could fit through, on, or in the models, like you would on the playground. One teacher then came up with the idea "to give them something and say, 'It needs to be able to use this.' Whether it's a small Lego person or something if they're building a slide, it needs to be able to go down your slide, or something that will give them a reason to make [their models] how it's supposed to be."

Along with the testing phase, the teachers considered other ways to further the children's understanding of the planning step of the EDP. For example, one of the teachers had put together a felt board with various pictures of playground equipment and other outdoor features on it. The purpose of this was so the children could create their own playground using already drawn pictures, "and then let them redo it…and an individual could also change it and also do their own playground design. And we [can] take pictures so that we have that recorded plan." The teachers also thought that maybe they could bring the children through much of the EDP by revisiting the water pipes on the playground they had used in week 2, "because that would be a good way, [to ask] 'How can we get the water to move? How can we get this boat from one end to the other?' Draw it and then see if we can build it and model it and test it."

Project Culmination

By week 5 of the project, the teachers were having the children draw a plan for a playground and then try to put that plan into a playdough model. Importantly, they were also noticing that the children still thought engineers build things, and were not differentiating between building models versus the real thing. On their own, the teachers had the idea of "what if we had one classroom draw the plans and give it to the other classroom to build it, so it's not building it so that might pull them away from it." Another teacher added that "I'm wondering if because we're having them plan it and then build models and then now they're gonna help us with this garden, they're thinking that engineers also do it, like the whole thing." They referenced their sessions with the local engineer who had been visiting the children. They explained that he had mentioned "passing [his plans] along, but [our children are] not passing it along to anyone, they're just doing it all, so maybe having them draw, pass it to the other class, and vice versa, maybe that will help separate it a little bit." At this point near the end of the project, the teachers, more so on their own than earlier in the project, were considering how to involve the children more within the EDP and even extend their knowledge of it past the end date of the project.

Finding #2: The teachers struggled, although showed improvement, with their ability to explicitly connect to the EDP while teaching the children.

Specifically:
1) The teachers did not often tell the children about how they were engaging in the EDP, particularly near the beginning of the project. This was true for planned as well as spontaneous engineering activities. (Spontaneous activities were engineering-like instances that children partook in on their own accord, unrelated to the overall project goals.)
2) The teachers showed some improvement by the end of the project with their ability to explicitly point out to children the connection to their EDP, but this happened more during planned engineering activities than it did for spontaneous engineering activities.

Project Beginning

One spontaneous engineering task that some of the children wanted to work on in the classroom during week 2 was to make purses out of duct tape. In this situation, the teacher working with the children prompted them and reflected afterward on how she had asked them "what can we do different?" when some things about their designs were not working. She also told them they were being engineers because "engineers make lots of things." While the teacher prompted the children with implied aspects of the design process, such as making things "different" and saying that engineers "make things," she never explicitly told them that they were participating in phases of the EDP or pointing this out on their classroom engineer's design tool.

During several planning sessions near the beginning of the project, the teachers began to admit that they forgot or did not include connections to the EDP when it arose. One teacher stated how "I don't think we did enough connecting to the word, 'test' and explaining to [the children] that we were testing. So that's something to think about in the coming days. Like just that they have to test it over and over again to make the product better." Another teacher reflected that "it would have been good to have the wheel right next to the water table," meaning their cardboard EDP, during a planned activity on making boats at the water table.

Project Midway

During week 3 of the project, the teachers were still forgetting to include steps of the EDP during their planned lessons. One teacher said that during her lesson to the first group of the morning "I forgot to tell them to think about it and plan it [but a child] just happen[ed] to think of that herself. So, I made a note of it and when I went to [the other teacher's group to teach it again] I had to make sure we told them" to plan. During that second time teaching the same lesson, when the teacher asked the children what they should do before building, a child also said they needed to "imagine" and the teacher agreed and told them to "make sure you plan and put it on the paper." She reflected "that [it] went a little bit better than the first group" because she remembered to bring up the EDP with the children. After this, another teacher then reflected on how "I think we are learning a lot about how to teach engineering…I think we have come far from where we started."

During the week 4 planning session, the researcher brought up how many of the children were still saying that "engineers fix things" and asked the teachers how they "might try to change that language." A teacher commented that "maybe they are misinterpreting improving for fixing. Cause I think that some of them are understanding but they just don't have the language." Another teacher added that "I honestly haven't paid attention to what we said to them as teachers, but it may even be that we said 'why don't you fix that if it isn't working?'" The teachers recognized that their own use of language may not have specifically connected to the EDP in a way that was helping the children best understand what engineers do. They decided that "if we say things like 'make it better' instead of fixing things" that it may help the children understand that what they are making is not broken but that all objects can be improved in some way.

Project Culmination

Despite this conversation about changing their language, during the week 5 planning session one of the teachers gave an account of working with a child during a spontaneous activity to make a pretend flashlight: "we put the clothespin through the hole and I said 'Okay, test it out. Tell me if you think it's okay.' And he came back and he said 'It's not right, something's wrong.' And I said 'Well, okay, how can we fix it?' So we fixed it. And then he went around and then it broke again, and I said 'Okay, well how can we fix it again?'" Although this teacher did use the word test with the child, which was part of their EDP, the idea of fixing something came up again. The researcher asked if "[the children] think about [what they are doing] as a step on the [EDP]? So that's what we want to get them to do is think about that test phase, right?" The teacher noted, "That's a good point," and another teacher subsequently reminded her "they're not fixing it, but changing it." It seemed like the teachers, although they were becoming better at reminding the children to plan and test, still struggled with making sure their own language during planned and spontaneous engineering activities represent their EDP and was true to what engineers do.

Once the project was over, the teachers reflected on the project and forward to the next few months. The teachers agreed that incorporating language specific to engineering was something important they learned. "I thought that we already do a lot of things to teach them how to be engineers and that it was just a language change, which is good. It's just a matter of [saying] 'Oh you're engineering that.' Or, 'You're designing like an Engineer.'" This later prompted another teacher to consider the week dedicated to working with water later that summer. She said how "the plan is to [do it] in a fun way, not a structured [way but] maybe we should probably bring the [EDP] wheel in. I didn't think about that but maybe we should look at that water week as giving it a little more structure instead of keeping it [unstructured]. I think that would be a good reinforcement." The hope was that through a continual focus on the EDP and what engineers do during this six-week project, the teachers as well as the children would continue to use engineering language in both planned and spontaneous activities throughout their school year.

Discussion and Limitations

Overall, the preschool teachers in this study were enthusiastic about teaching engineering and engaging children in a long-term engineering project focused on changing some things about their outdoor play area. Throughout the six week project they were each active participants in the planning and implementation process, contributing their ideas and each taking turns planning and

teaching lessons. This was important to their success because, as Bagiati and Evangelou found "the success of curricular innovation along the lines of engineering content in a preschool classroom depends on the level of engagement that multiple stakeholders have in the process" [32, pp. 126]. In this preschool, the director was fully supportive of the project, the parents of the children were intrigued by the project and talked of how they liked that it was happening, and the teachers were willing to learn engineering with the children.

The teachers, at times throughout all six weeks of the project, struggled with the EDP. This was new to them; although they had seen the researcher teach engineering to the children prior to the study and include the EDP, in other engineering tasks that happened in the preschool, the children mainly created and constructed without being asked to engage in other possible steps of the EDP. Perhaps because this was their first experience with the EDP, throughout the entire project the teachers rarely referred to the EDP by its true name, both in lessons and during planning sessions. The cardboard EDP that the children and teachers made was called an "engineering tool," and early on in the project a teacher kept referring to it as "the kind of clock thing, the circular steps." They consistently called the cardboard EDP "the wheel" in front of the children, or that and "the stages" during the planning sessions. As other researchers have noted, engineering can be intimidating for many teachers as they try to plan complicated engineering activities that seemingly have many steps to them [27]. These teachers may have felt intimidated by the EDP, contributing to their use of more generic names for it.

The preschool teachers improved their ability to recognize that they needed to better include elements of their EDP, both in planning ahead for lessons and when on the spot during teaching. Their novice use of the EDP is similar to a study of preservice elementary teachers who were just learning to use the EDP [47]. The preservice teachers were able to point out broad instances of the EDP happening when watching videos, but were not able to elaborate on specific engineering practices or identify specific moments in the videos when students were engaging in them. This was different than professional engineers who watched the same videos, and clearly more expert at the EDP although novices at teaching in elementary classrooms. The engineers were more likely to point to specific video evidence of engineering practices taking place in a classroom. Perhaps what the preschool teachers needed in the current study was simply more time and practice than the six week project enabled for fully developing their comfort level and use of the EDP. Tuttle et al. [34] noted similarly that video observations of the teachers in their study showed that large changes to classroom practice using the EDP did not occur immediately, and is likely to need further professional development and scaffolding for teachers.

It may also be that the preschool teachers questioned their students' abilities to fully engage in elements of the EDP that they had chosen to include. This was evident during the week 2 conversation mentioned earlier when the teachers were unsure about asking the children to plan on paper what they were going to construct. As time went on, the teachers eventually included this, and the children were highly successful with planning models before creating them for several different activities. However, these findings may be supported by Nadelson et al.'s study which posited that "it is likely that the teachers did not think that their students were ready to engage in the highest levels of design because of lack of experience with the process. It may also be possible that the teachers' lack of experience in teaching using design constrained their ability" [36, pp. 39] to create lessons that included more abstract concepts of designing like

imagining and planning. Alternatively, it may be that the preschool teachers were not all that concerned with their students' abilities to specifically implement aspects of EDP, a speculation that Nadelson et al. [36] shares about the teachers in her study as well. The hope is that by introducing the teachers to the EDP, combined with their already positive views of engineering, that they will be able to more intentionally include the EDP in future activities in their classrooms [24].

Several limitations exist for this study. The data presented here are just one subset of the data collected as part of this study. Future analysis of the data should examine the teachers' use of engineering language and EDP terms during the video recorded lessons. Additionally, all of the children in the preschool participated in interviews as a pre- and post-test for their engineering knowledge. Their use of engineering language from pre- to post-test, as well as how that use of engineering language aligns with how the teachers talked about engineering, will tell more about children's abilities to learn elements of the EDP, and the influence of the teachers use of engineering-specific language while teaching. Finally, due to unforeseen circumstances at the campus preschool, it has been permanently closed. Therefore, follow up in this setting and with these teachers to understand the long-term effects of participating in this program is impossible to discern.

Conclusion

Teaching engineering involves a different way of approaching curricula than what many teachers are used to, with its focus on open-ended, multi-answer problems. Few to no preschool teachers have a background in engineering, yet many believe engineering is important to teach young children. The four preschool teachers in this study had a beginning knowledge of and positive attitudes toward teaching engineering. The preschool teachers were guided by the researcher to explicitly include the EDP in a six-week project for children to redesign the outdoor play area while expanding their engineering curriculum to include tasks less familiar to the children. Findings from this study showed that the preschool teachers' ability to plan for and implement specific components of the EDP improved over the course of the six-week study, moving from the researcher having to consistently remind the teachers of the EDP and the teachers unsure about how to include steps, to the teachers being able to plan for some parts of the EDP on their own and with minimal prompting by the researcher. The teachers struggled more, although showed improvement, with their ability to connect to the EDP while teaching the children and be explicit with them about how they were engaging in the EDP. During engineering activities, continually highlighting children's abilities to utilize more abstract components of the EDP may help teachers understand when and how young children can engage in these steps. Reflecting on missed opportunities for teaching the EDP also seemed to help this group of teachers, over time, become more cognizant of their own use of language and explicit connections to the EDP during activities with the children.

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