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5th/6th Graders and Preservice Teachers Explore Engineering and Coding in a Combined After-School Technology Club/Educational Technology Course

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Abstract: Elementary schools are increasingly encouraged to adopt STEM education efforts that include engineering and programming, yet pre-service teachers (PSTs) are not traditionally prepared to teach these subjects. This pilot study describes an innovative preparation experience designed to help PSTs gain experience and confidence in these areas. As part of an undergraduate educational technology course, PSTs led an after-school technology club at a local public school. PSTs enrolled in the course worked alongside fifth and sixth grade students on a series of collaborative design challenges that culminated in the creation of animal-inspired robots. The "WoW Club", as it came to be known, introduced both student populations to engineering, coding, and robotics, while allowing them to interact and develop skills in a low-stakes environment. The approach was found to have a positive impact on PSTs' engineering self-efficacy and coding self-efficacy.

Purpose

Elementary schools are increasingly embracing engineering and programming within STEM education. The Next Generation Science Standards (NGSS) call for the engineering design process to be emphasized as much as scientific investigation and for students to begin learning about it in kindergarten (NGSS Lead States, 2013). Virginia updated its Science Standards of Learning to include engineering practices and became the first state to require computer science education when it adopted the *K-12 Computer Science Standards of Learning* in 2017 (Sawchuck, 2017). Other states are establishing similar standards, introducing programming at the earliest educational levels (Neary, 2016; Stanton, Goldsmith, Adrion et al., 2017).

Despite these efforts, many elementary students are not introduced to engineering and coding in school (Bybee, 2010; Carr, Bennett & Strobel, 2012). One reason for this is teachers' lack of familiarity with the topics and lack of confidence in the underlying disciplines of mathematics and science (Hsu, Purzer & Cardella, 2011). Hsu et al. (2011) found that elementary school teachers believed that it was important to incorporate engineering into their curricula, but did not feel confident teaching it. Most pre-service teachers (PSTs), especially those pursuing licensure in elementary education, are not exposed to engineering or coding in their coursework. As of Spring 2017, only nine higher education programs in the US provided courses or curricular programs for elementary education majors to develop content knowledge in technology and engineering (Rose, Carter, Brown, & Shumway, 2017).

This dearth of appropriate instruction conflicts with prior research suggesting that P-6 PSTs must receive training in engineering topics, feel confident in their abilities to teach them, and be willing to adopt new teaching practices, to integrate engineering into their classrooms (Rich, Jones, Belikov, Yoshikawa, & Perkins, 2017). If teachers are to feel confident teaching engineering and computer science, they will need experience doing so. Thus, it is crucial to develop teacher preparation programs capable of equipping teachers with the necessary knowledge and skills in teaching these topics (Grover & Pea, 2013).

In Spring 2018, an education faculty member partnered with an engineering professor to introduce PSTs to engineering and programming within the context of an educational technology course, T430. Eight enrolled students met at a local school alongside eighteen 5th and 6th graders (FSGs) who were recruited for an after-school technology club. The group of PSTs and FSGs became collectively known as "The WoW Club". Over the course of ten weeks, WoW Club participants explored educational technologies and completed programming activities that culminated in the creation of animal-inspired robots. The overall goal was to enhance PSTs' engineering knowledge, engineering beliefs, engineering self-efficacy, coding self-efficacy, and intention to integrate engineering into their instruction.

Intervention

T430 is required for all PSTs. It includes twelve modules intended to enhance students' technological pedagogical knowledge (Koehler & Mishra, 2009). Students explore various educational technologies, particularly those that support creation and collaboration, as well as tools that facilitate assessment and differentiation. The modified section differed from the traditional section in three major ways. First, starting in the sixth week, the weekly class met at a local school alongside eighteen FSGs in the context of an after-school technology club. This setting allowed the PSTs to teach and learn with FSGs, providing a model of technology integration within a low-stakes environment. Second, PSTs helped plan and implement the instructional activities, giving them much more responsibility and accountability than typically possible in an education course. Third, an engineering and coding project was included.

The PSTs and FSGs were organized into small teams (1-2 PSTs and 2-3 FSGs) and tasked with building animal-inspired robots using readily available materials, as well as LEDs, speakers, and servo motors. Robots were required to have at least one moving part. To accomplish this, teams had to design a mechanism to attach the motor to their robot. For example, one team used four-bar linkages built of straws to achieve wing flapping in a dragon-inspired robot (Figure 1). All robots needed to use a minimum of one LED light and to produce sound. Accordingly, both student groups learned basic block programming with Arduino, using mBlock, a Scratch derivative. Later, teams produced narrative videos featuring their robots using chroma key technology. Figure 2 shows the students progressing through the various project stages.

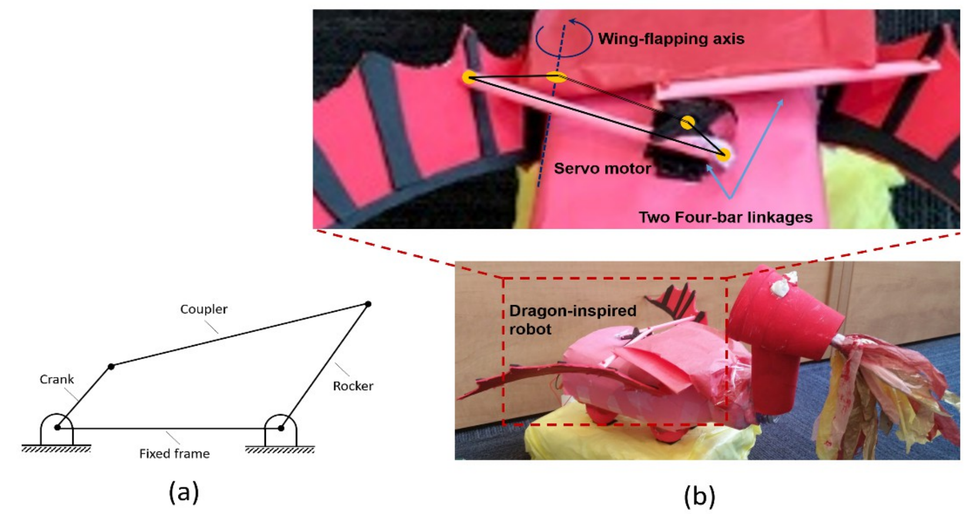

Figure 1. (a) Schematic of a four-bar linkage, a widely used mechanism in Engineering. (b) Illustration of flapping-wing mechanism in the Dragon-inspired robot, built using four-bar linkages.
Figure 2. FSGs and PSTs making animal-inspired robots.

T430 approaches technology as a tool to enhance student learning. Accordingly, as part of their course requirements, PSTs are expected to plan lessons that integrate technology in their intended teaching area. In order to provide a model of integration where technology and engineering enhance instruction in other subjects, a world cultures theme was selected for the after school club and it was christened "The WoW (Where in Our World?) Club". The animal-inspired robots project incorporated geometry, biology, geography, music, art, narrative structure, research, and oral communication skills. This confluence of subjects can be seen in each team's robot (Figure 3) and their videos (https://www.youtube.com/watch?v=hK6e8PE3BHY).

Methods & Data Sources

A mixed methods approach was used to explore the impact of the modified section of T430. Two data sources were used: an end-of-course online quantitative survey and a focus group interview. Seven PSTs participated in the program: two secondary English, one secondary History, and four elementary. In order to compare the participants' attitudes to non-participants, two comparison groups were used. Students in a prerequisite course (T301) taught by the same instructor and students in an unmodified section of T430 taught by another instructor took the quantitative survey. The 5-point likert scale survey was constructed based on existing instruments to evaluate PSTs' knowledge of engineering concepts (*K*), beliefs about engineering (*B*), engineering self-efficacy (*ESE*), intention to integrate engineering (*ItIE*), and coding self-efficacy (*CSE*) (Fitzgerald & Cunningham, 2013; Lachapelle et al., 2014; Rich et al., 2017; Yasar et al., 2006; Yoon, Evans, & Strobel, 2012). Five students from the modified T430 course participated in the focus group. The qualitative data was hand-coded using a grounded theory approach (Charmaz, 2006). One researcher identified emergent themes. These themes were reviewed by another researcher and modified as needed to achieve agreement. All data was then coded using the agreed-upon themes.

Findings

The quantitative data was analyzed to explore whether the modified T430 course influenced the participating PSTs' *knowledge of engineering concepts* (*K*), *beliefs about engineering* (*B*), *engineering self-efficacy* (*ESE*), *intention to integrate engineering* (*ItIE*), and *coding self-efficacy* (*CSE*). There were significant differences in *engineering self-efficacy* ($F = 3.84$, $p < 0.05$) and *coding self-efficacy* ($F = 5.70$, $p < 0.01$) across groups. Participants showed higher self-efficacy than PSTs in the comparison courses: T301 ($p < 0.01$) and the alternate section of T430 ($p < 0.05$). There were no significant differences for knowledge of engineering concepts, beliefs about engineering, and intention to integrate engineering. The sample sizes were quite small, so finding significant differences across two variables was quite promising.

Seven themes were identified into the qualitative data (see Table 1). A disconnect was detected between PSTs' beliefs about engineering and their intention to integrate it into other subjects. The education students unanimously agreed that engineering skills are important and valued by students, parents, and school districts, but many PSTs reported low levels of interest in engineering and struggled to see how engineering could be incorporated in their future classrooms. As one PST said, "I would feel confident [integrating engineering]...but I don't like engineering." The PSTs identified barriers to integrating engineering, including a perception that engineering was not compatible with the grade level they plan to teach (i.e. early elementary) or their selected content area (i.e. English), and concerns regarding access to technology. One PST admitted that she "did not really understand" engineering and robotics, and felt that the two are "not easy to mix with class," especially when teachers "have to teach to the [standards]". These comments suggest PSTs may need substantial modeling and hands-on experience to feel prepared to integrate engineering.

Table 1. PST Focus Group Themes

Theme	Frequency	Quote
Value of Engineering	5	"The parents look at engineering almost like an adventure. They were really excited that their kids were doing it and you could just see the glow on their face"
Interest in Engineering	7	"I'm confident in my abilities now, but I don't like engineering"
Intention to Integrate Engineering	8	"I would like to because I had the idea to maybe incorporate something like once a month….but in the real world picture? No, I don't see it being integrated."
Perceived Barriers	6	"Yeah if you're in [a low-income area] you wouldn't have access to these resources, like the money or even a university to help get it running."
Value of Experience with Students	7	"I felt like I was already on the job...I had a lot more responsibility. That felt like I was actually teaching."
Fifth & Sixth Graders' Skill Development	4	"I think it really built their confidence, which was cool. Especially when they're teaching a college student."
The Iterative Process	5	"There were technical issues...but that's life."

Despite these reservations, PSTs felt that their knowledge of engineering and pedagogy increased. One PST described the experience of "working to create meaningful and unique artifacts" as an effective "means of introducing students to engineering concepts." They appreciated the practical experience, characterizing it as "way more hands-on" than traditional classes and an opportunity to develop a professional identity in a low-stakes environment. One PST summarized succinctly: "I got to try out all these ideas and philosophies I have...and not really worry about the consequences." They also reported that their FSG partners developed agency, confidence, and practical skills. As one PST put it, the WoW Club "really built their confidence" and "it wasn't me teaching them at the end, they were teaching me".

Scholarly Significance

Efforts to promote STEM education rely on the presence of teachers equipped with the skills and confidence to incorporate these subjects into their lesson plans. This pilot study explored the impact of an innovative approach to introducing PSTs to engineering and coding, and contributes to the research on preparing STEM teachers. It was predicted that providing PSTs with the opportunity to participate in an engineering and programming project alongside FSGs in a low-stakes environment would enhance beliefs that encourage adoption, such as perceived value and self-efficacy, and reduce conceptions that inhibit adoption, such as perceived complexity (Rich et al., 2017; Tornatzky & Klein, 1982). PSTs' self-efficacy for engineering and coding did increase, showing the promise of both robotics and the low-stakes context, however, several participants were unsure whether they would integrate engineering into their instruction.

PSTs may be hesitant to adopt new innovations generally. Tillman (2013) examined the effect of introducing digital fabrication in an educational technology course. He found that although PST's' self-efficacy increased, few mentioned digital fabrication when asked how they planned to integrate technology. Instead, PSTs mentioned technologies adopted by a majority of elementary teachers e.g. interactive whiteboards, video, class websites. His conclusion is that PSTs feel more confident using standard classroom technologies. The same may be true here. PSTs can develop skills and confidence with engineering and coding during teacher preparation, but until they see these subjects routinely integrated into classrooms, they may remain hesitant to implement them. With the adoption of Virginia's revised Science standards, teachers may be forced to integrate more engineering practices into their instruction, resulting in more buy-in from PSTs. However, it remains to be seen how these curricular changes will manifest in classroom practices. This study is limited by its small sample size, its specific context within an after-school technology club, and its focus on robotics. More research is needed to help uncover the connection between PSTs' abilities, beliefs, and intention to integrate engineering, and interventions that can motivate PSTs to integrate engineering and coding into their instruction.

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