“Zooming In” on Robotics during COVID-19: A Preservice Teacher, an Engineering Student, and a 5th Grader Engineer Robotic Flowers via Zoom

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Abstract: The COVID-19 induced school shutdown dramatically decreased students’ hands-on STEM learning opportunities. An NSF-funded program partnering preservice teachers and undergraduate engineering students to teach robotics to fifth graders was adapted to a virtual format via Zoom. A case study intimately explored one team’s experience as they engineered bio-inspired robots over five weekly sessions. Zoom recordings, written reflections, and lesson slides were analyzed to describe how the virtual context shaped the lesson and influenced the preservice teacher’s experience. All three participants successfully engineered a robotic flower indicating hands-on robotics instruction is feasible in an online format. The virtual context increased the preservice teacher’s responsibilities and sense of autonomy, and appeared to positively influence her knowledge and self-efficacy. Despite technical challenges, positive outcomes suggest the approach is worth repeating. To the authors’ knowledge, this is the first study examining a virtual robotics lesson co-taught by a preservice teacher and an engineering student.

Introduction

In March 2020, most schools in the United States closed their buildings and moved instruction online, dramatically decreasing hands-on STEM learning opportunities for K-12 and college students alike. This case study describes how Ed+gineering, an NSF-funded program, adapted hands-on robotics instruction in response to the COVID-19 pandemic. The study’s purpose is to intimately explore the experience of one preservice teacher as she collaborated virtually with an undergraduate engineering student and a fifth grader to design and build bio-inspired robots in an adapted-to-be-virtual after-school technology club. This in-depth exploration provides insight into how the Zoom-based virtual context influenced the lesson events and learning experiences of the preservice teacher.

Related Literature

While COVID-19 forced schools to shift online unexpectedly, online instruction in K-12 and higher education has been growing steadily for decades (Kennedy & Archambault 2012; Picciano et al. 2012). Meanwhile teacher education programs are only beginning to prepare candidates for teaching online (Archambault et al. 2016). Little is known about preservice teachers’ experiences interacting virtually with K-12 students, and even less about preservice teachers’ ability to adapt from interacting face-to-face with children to interacting online via synchronous web-based tools, like Zoom.

While numerous studies report online learning in both higher education and K-12 settings produce equivalent or better student outcomes when compared to face-to-face instruction (Means 2009; Patrick & Powell 2009), some disciplines are better suited for virtual instruction. Courses that incorporate engineering design are more challenging to implement online due to the need for supplies, the focus on hands-on experiences and teamwork, and lack of teacher training (Alkhatib 2018; Ashton 2014). Few studies have examined K-12 online engineering instruction and preservice teachers' participation in such activities.

Growing evidence supports robotics as a powerful approach to STEM learning for elementary students (Rogers & Portsmore 2004) and preservice teachers (Bers & Portsmore 2005; Jaipal-Jamani & Angeli 2017; Kidd et al. 2020; Kim et al. 2015). Robotics merges the engineering design process (EDP) with computational thinking by engaging students in the construction of three dimensional artifacts they control via coding. Because robotics involves the manipulation of physical artifacts, it is challenging to implement virtually. Virtual robotics programs do exist, but they tend to engage participants in controlling simulations or remotely operating robots (Witherspoon et al. 2017). Minimal research exists on virtual robotics experiences that engage K-12 students or preservice teachers in the hands-on construction and control of physical robotic systems. Little is understood about the feasibility of using virtual platforms to guide students through robot design and coding.

Social constructivism suggests that cross-disciplinary collaboration prompts students to experience new perspectives as they build knowledge together (Piaget, 1985). The Ed+gineering project positioned preservice teachers, engineering students, and fifth graders to share expertise from their respective disciplines and personal experiences as they collaborated virtually to design robots to address global challenges. Prior cross-disciplinary research found positive benefits for preservice teachers and engineering students who co-taught engineering lessons to elementary students (Bers & Portsmore 2005; Fogg-Rogers et al. 2017). Our prior research related to the Ed+gineering project suggests preservice teachers who partner with engineering students to teach robotics to fifth graders show an increase in coding knowledge and coding self-efficacy (Kidd et al. 2020). Self-efficacy, or "people's beliefs about their capabilities" (Bandura 1993, p. 118), is developed from social experiences and self-perception, and is influential in determining outcomes. Teacher self-efficacy has been linked to willingness to adopt innovative teaching strategies (Tschannen-Moran & McMaster, 2009), intention to use technology (Teo, 2009), and improved student performance (Caprara et al., 2006). Other researchers have likewise found the experience of teaching STEM lessons enhances teaching self-efficacy (Fenton & Essler-Petty 2019; Fogg-Rogers et al., 2017; Rich et al., 2017). To the authors' knowledge, this is the first study examining a virtual robotics lesson co-taught by a preservice teacher and an engineering student.

Research indicates that preservice teachers benefit from experience teaching K-12 students in authentic contexts (Hunter & Botchwey 2017; Polman & Westhoff 2004). The Spring 2020 semester offered preservice teachers a unique opportunity to experience an authentic and novel K-12 context: participating in COVID-19-adapted virtual sessions. This case study aims to uncover what happened when a preservice teacher and engineering student co-taught a multi-session, virtual robotics lesson to a fifth grader during the COVID-19 pandemic and how this experience affected the preservice teacher. Because so little research exists related to preservice teachers teaching robots online and because the robotics lesson taught by the preservice teacher was adapted to a virtual context, rather than intentionally designed for online delivery, we started with a research question that was purposefully open-ended. The intention was to dissect the lesson, noting both planned and unplanned events, and the participants' responses to those events, in order to determine how the virtual context altered the participants' experiences. Our previous research on the Ed+gineering project suggested that collaboratively teaching robotics has a positive influence on preservice teachers' knowledge and self-efficacy. We wanted to learn how the virtual delivery model influenced those outcomes and how the preservice teacher evaluated her experience. Accordingly, the research questions for this study were:

1. What occurred during the team's Zoom sessions? How did the virtual context shape the lesson events and influence the interaction between the participants?
2. How did teaching in the virtual context influence the preservice teacher's robotics/engineering knowledge and self-efficacy?
3. What benefits and challenges did the preservice teacher report associated with teaching robotics collaboratively via Zoom?

Methods & Context

This study focused on the virtual robotics lesson and learning experiences of one of nineteen teams that participated in an NSF-funded collaboration aimed at improving preservice teachers' competence and confidence integrating engineering into PreK-6 classroom instruction. Each team included a preservice teacher enrolled in an instructional technology course, an undergraduate engineering student enrolled in an electromechanical systems course, and a fifth grader participating in an after-school technology club (the “WoW Club”) run by the preservice teachers in the educational technology course. The WoW Club meetings were held during the undergraduate students’ course time so they could attend the club sessions as part of their course requirements. Each collaborating preservice teacher and engineering student planned a lesson centered around the engineering design challenge of building and coding a bio-inspired robot that could address a global challenge. The lesson was originally designed to be delivered in person at a school site over the course of five weekly WoW Club meetings, but when schools closed in response to COVID-19, it was migrated online for delivery via Zoom.

A case study was selected because of the intervention’s unique nature. The researchers wanted to understand what transpired during the Zoom sessions, how the online context influenced participants’ learning experiences, and if the model was worthy of replication. The study is thus intended to be both descriptive and exploratory (Baxter & Jack 2008; Yin, 2003). The virtually-adapted WoW Club is the case and each team is a potential embedded unit within that case (Baxter & Jack 2008). “Team Flower” was selected as a representative team because their overall performance was in the middle of the nineteen teams (i.e. they produced robots that were neither the most, nor the least, sophisticated in the group). This paper focuses exclusively on Team Flower in order to provide a rich account of one team’s entire 5-week experience. A future publication is planned to illuminate the experience of multiple teams. Team Flower members included Brianna, black female preservice teacher, Craig, a white male engineering student, and Keith, a black male fifth grader (names are pseudonyms).

Prior to school closures, each team was preparing to teach their robotics lessons during the after-school technology club. The WoW Club, led by the first author and twenty preservice teachers in her instructional technology class, provided a low-risk environment for the preservice teachers and fifth graders to use educational technologies to explore the club’s interdisciplinary theme of global challenges. Earlier, the preservice teachers had collaborated with eighteen engineering students in the second author’s electromechanical systems course to build simple animal-themed robots using Hummingbird robotics kits (see Fig. 1). After this, each team planned a three-part robotics lesson to deliver to one of twenty fifth graders participating in the WoW Club. The lesson goals and structure were provided to the teams by the instructors. The preservice teachers and engineering students filled in the details of how the lesson objectives would be met. The lesson was scaffolded into three main parts: 1) an introduction to robotics and the Hummingbird robotics kits the participants would use to build their robots; 2) an introduction to bio-inspired robotics and robots that are used to address global challenges; and 3) building, coding, and testing a bio-inspired robot. Each team chose the global challenge they would address and the bio-inspiration for their proposed solution.

Figure 1: Preservice teacher, Briana, and engineering student, Criag, collaborated to design, build, and code a robotic chameleon prior to planning their lesson for Keith. Cerberus’ tail wags when petted (activated via distance sensor) and eyes light up when spoken to (activated via sound sensor).

When schools closed, the instructors moved the robotics lessons, and the after-school technology club during which the lessons were to occur, online. Many changes were made in order to implement the club and the lessons virtually. The most significant change was delivery modality, which in turn impacted the role and responsibility of the preservice teachers. Instead of two-hour weekly club meetings held at a local school, virtual WoW Club consisted of 19 simultaneously occurring weekly Zoom meetings. Each week during the regular club meeting time, each preservice teacher hosted his/her own Zoom session in which she/he would teach part of the robotics lesson. The focus and goals for the Zoom sessions were set by the instructors, but the structure and length were determined by the teams in response to their needs. Teams met for 4 or 5 weeks to complete the project with engineering students participating for the first hour of most sessions. Because the preservice teachers hosted the Zoom meetings and were expected to be present at all sessions, they were primarily responsible for structuring the sessions and navigating the Zoom platform. This new responsibility expanded the role and expectations of the preservice teachers. As they were likely to be alone with their fifth grade partners for at least part of the time in the Zoom sessions, the preservice teachers bore more responsibility for understanding the lesson content.

The roles of the instructors also changed. The online delivery mode shifted the instructors' responsibilities from leading course/club meetings to providing logistical and technical support in Zoom sessions. The individual Zoom sessions also made it difficult for the preservice teachers to collectively reflect immediately following the club sessions, as they had been accustomed. The education course instructor initiated an additional one-hour weekly virtual meeting for her students, in which they could share struggles and successes teaching robotics virtually.

Another major change related to supplies. The instructors delivered Hummingbird robotics kits to each participating preservice teacher, engineering student, and fifth grader. Because the participants were no longer sharing a single kit within their team and had continuous access to the robotic components for the duration of the project, this enabled a pedagogical change. Instead of collaborating on a single team robot, each participant was encouraged to build their own robot based on their team's chosen theme (see Fig. 2). This change increased the expectations for the preservice teachers. In the face-to-face context, the preservice teachers could play a supporting role in the design and coding of a single team robot. In the virtual context, the preservice teachers were the sole designers of their own individual robots.

Parents' roles were also impacted by the move to virtual learning. They played a more active role, assisting children with obtaining supplies and logging into Zoom, and communicating regularly with the instructor. Some parents chose to participate in the construction of the robots. Parents and family members were encouraged to participate in a virtual showcase event where teams presented their robots and an accompanying *Shark Tank* pitch.

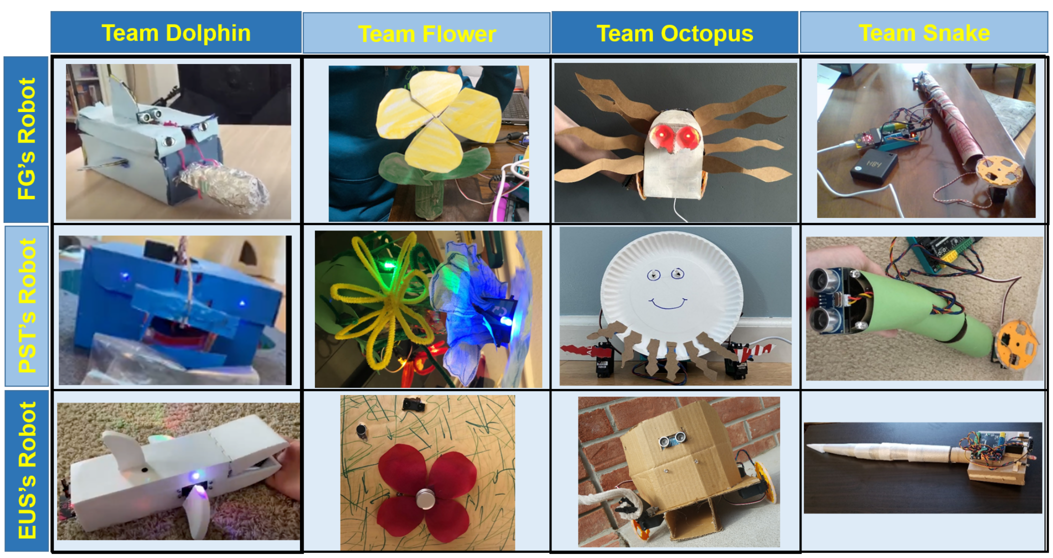

Figure 2. Examples of robots built by fifth graders, preservice teachers, and undergraduate engineering students in different teams. Every team member built a robot version of the bio-inspiration chosen by the team.

Data Sources & Analysis

Three data types were used to provide a holistic understanding of Team Flower's experience: five Zoom recordings (~1.5 hr/each), preservice teacher and engineering student written reflections, and showcase slides presenting the team's finalized robots and *Shark Tank* pitch.

As only one team's video was selected for analysis (Derry 2007), two researchers watched each of the team's five recordings, taking extensive field notes to chronologically document all important lesson events and conversations. The pair discussed each session in depth, considering the preservice teacher's engineering and robotics knowledge, confidence, pedagogy–including the extent to which she used an inquiry-based engineering design process and educational technology to support student learning–, and overall lesson success. This evaluation was guided by a series of formative rubrics developed by the team to evaluate elementary-level engineering lessons. A third member of the research team–a different member for each session–then evaluated each recording using the same rubrics to increase the trustworthiness of the analysis. The three researchers discussed each recording until they reached a consensus on the awarded scores. This process was especially beneficial as education and engineering faculty members often highlighted different aspects of the sessions (e.g. culturally responsive pedagogy vs brainstorming process) and it required the group to agree on what constitutes effective engineering pedagogy and what that pedagogy looks like in the context of a Zoom session with a single student. Following each discussion, a lesson summary was generated listing: events related to the engineering design process, notable unplanned events (e.g. interaction with a parent), lesson strengths, and lesson weaknesses/challenges. These summaries were used to identify trends throughout the series of five Zoom sessions. The trends were then validated by a second researcher.

Written reflections from the preservice teacher were examined using a thematic analysis approach incorporating deductive and inductive strategies (Elo & Kyngas 2008). The text was analyzed first deductively to: 1) locate passages related to the preservice teacher's knowledge of, and self-efficacy for, engineering/robotics based on our prior research that showed an increase in preservice teacher coding knowledge and self-efficacy after teaching lessons in the face-to-face WoW Club, and 2) identify challenges and benefits explicitly named by the college students. This was followed by an inductive approach to identify any emergent themes that could shed light on lesson events or the participants' experiences. The showcase slides were used to examine the final artifacts (robots and *Shark Tank* pitch) produced by the team. Data from the three sources were integrated to address each research question. The findings, organized by research question, are presented below.

Findings/Results

RQ1: What occurred during the team's Zoom sessions? How did the virtual context shape the lesson events and influence the interaction between the participants?

Team Flower's lesson content, organized around an engineering design process, was distributed over its five Zoom sessions; with background research, brainstorming, and blueprinting occuring in sessions 1-2; building and coding robots occurring in session 3; and the crafting of a *Shark Tank* video pitch to entice theoretical investors occurring in sessions 4-5. Slides illustrating these processes can be seen in Fig. 3. Very little time was dedicated to didactic teaching; the great majority of the lesson was structured as a collaborative learning experience, with team members working simultaneously on project tasks. The five Zoom sessions culminated in the production of three flower-inspired robots, one engineered by each team member, and a *Shark Tank* video pitch promoting the team's conception of a flower robot that could safely pollinate bees to help prevent bee colony collapse and extinction.

Technological challenges were consistent throughout the lesson series. For example, the team was repeatedly tested by their inability to share the same physical space with their partners and by the tools that provided windows into each other's environment. Relying on webcams and screen sharing to identify problems and communicate solutions often resulted in tedious exchanges (e.g. Keith: "I did that. Look at my screen." Brianna: "I am looking. I don't see all that on your screen. Maybe you're not sharing that."). It was not always easy for team members to hear each other or see what others were doing. Sharing resources (e.g. YouTube) over unstable/slow connections and navigating multiple platforms and applications (e.g. Zoom, Google Slides, Make Code - used for coding Hummingbird components, WeVideo - used to create the *Shark Tank* pitch) on small computer screens added to the technical challenges. Keith's older computer with a slower processor further complicated tasks. Brianna often had to redirect Keith to other tasks while waiting for his computer to respond (e.g. Brianna: "Be patient with it. You're gonna make it mad. Just let it load. Your computer's thinking. Thinking hard."). With time, the team's adaptations became more innovative (e.g., Brianna connected to Zoom on one device and edited their video on another; Keith texted his contributions to the *Shark Tank* pitch to Brianna). Despite these challenges, which were largely out of the control of the participants, the researchers observed excellent use of educational technology. Multiple tools were leveraged to promote active engagement, support collaboration, document team progress, assess student understanding, and produce lesson artifacts. Nevertheless, some technical issues remained unresolved. For example, Keith (fifth grader) consistently had trouble uploading code onto the microbit which controlled his robot and his servo motor stopped working in session three, and never regained functionality.

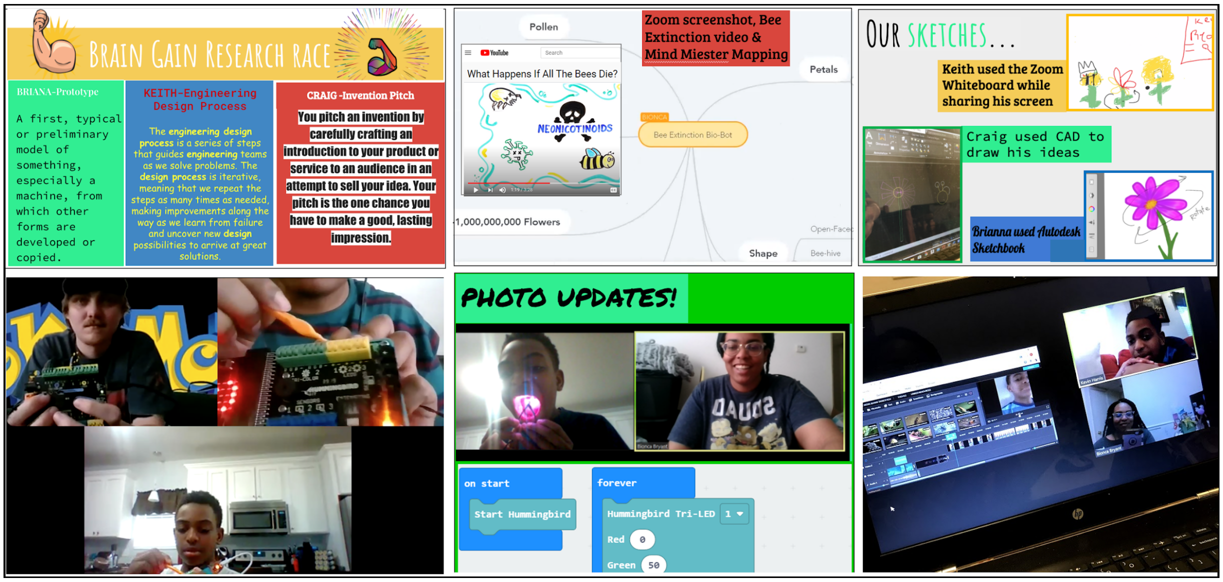

Figure 3: A visual summary of engineering design process-related lesson events. Each slide represents a different activity: researching, brainstorming, blueprinting, connecting hardware, coding, and crafting the product pitch.

The on-site WoW club sessions that occured prior to the school shut down were less formal than a regular classroom. The virtual context increased the informality, with pets, family members, and off-task, silly behavior from the fifth grader creating frequent diversions. These diversions did detract from the lesson objectives, but they also created opportunities to build rapport (e.g. fifth grader sharing family pictures from his bedroom). Brianna (PST) and Keith (fifth grader) collaborated in WoW club meetings prior to the robotics project and had already formed a strong bond. Their relationship was evident as a driving force throughout the Zoom sessions. Brianna clearly planned lesson activities with Keith in mind and was very committed to supporting his development. The final two lessons were almost entirely dedicated to developing the showcase slides and *Shark Tank* pitch (see Fig. 4), highlighting Keith's dramatic talents (e.g. he sings/raps part of the pitch) and interest in entrepreneurship. "I'm the businessman here," he says in one session. This relationship seemed to be motivational for Keith, as he was repeatedly observed trying to impress Brianna, and the two often teased each other affectionately. On the other hand, Craig's (engineering student) position as a relative outsider, coupled with his shier, more reserved personality, may have discouraged him from contributing more actively within the triad. A reflection comment seemed to confirm this: he suggested a session with just the engineering student and fifth grader could improve the project.

Brianna's affection for and dedication to Keith was identified as an emergent theme in her reflections (e.g. "I saw so much of myself in him and I immediately knew that he was capable of anything…. I felt it was my duty to protect and push him to his fullest potential, to defy every odd." - see Tab. 1). Her commitment to Keith's learning may have helped her patiently and consistently address his needs throughout the sessions. Keith's attention wavered frequently, especially when technical issues prevented him from working actively on his robot or *Shark Tank* pitch. When his focus drifted, Keith often engaged in silly antics, for example, using the Zoom white board feature to draw on Brianna's shared screen. Brianna regularly refocused Keith's attention, checked for his understanding of important concepts, provided clear step-by-step directions, and repeated directions multiple times. To maintain his engagement, Brianna used active learning strategies, regularly soliciting Keith's ideas, and avoided lecture-based interactions. She used Keith's interests and pop cultural references (e.g. Black Panther) to explain technical concepts (e.g. biomimicry) and allowed Keith the space to experiment with designs that failed. In these ways Brianna demonstrated culturally responsive engineering pedagogy. Culturally Responsive Pedagogy (CRP) has been defined by Gay and Kirkland (2003) as a way in which educators use the "cultures, experiences, and perspectives of African, Native, Latino, and Asian American students as filters through which to teach them academic knowledge and skills …..". Engineering pedagogy includes approaches such as the use of brainstorming in solution design, the consideration of multiple solutions and paths, and the tolerance for failure as part of the design of solutions

(Cunningham & Carlsen, 2014). Engineering pedagogy differs from traditional pedagogies in that it relies on interaction, hands-on activities, consideration of real contexts of application, and promoting creativity (Mbodila et al., 2012; Hayes et al., 2016).

Figure 4: Team Flower's showcase slides (pictures of team robots and *Shark Tank* presentation)

RQ 2: How did teaching in the virtual context influence the preservice teacher's knowledge and self-efficacy?

Brianna confidently presented engineering and robotics content throughout the Zoom sessions. She dominated lesson delivery, setting the agenda and leading every activity. Her control of the lesson structure suggests she dominated the lesson planning process as well. Her reflections support this conclusion (e.g. "Most of the ideas and delivery came from me."). However, there were multiple opportunities where engineering and robotics content could have been introduced and/or explored with greater depth. For instance, at no point in the five sessions were examples provided of robots designed to address global challenges. Additionally, Brianna's and Keith's robots reflected a solid, but basic, understanding of robotics/engineering, incorporating lights and servos. In contrast, Craig's design integrated sensors and conditional coding to react to bees' behavior. Had Craig, or another engineering student, played a larger role in the lesson, the instructional level may have increased, and perhaps Keith's motor issue could have been corrected. While the Zoom-induced team isolation expanded Brianna's role, increased her responsibility, and may have increased her initiative, it decreased opportunities for her to learn from instructors or other classmates. Had Team Flower's robotics lesson occurred in a classroom as originally planned, an instructor, teaching-assistant, or more knowledgeable classmate could have addressed technical concerns (e.g. Keith's uploading and servo motor issues) and enhanced Brianna's knowledge. It is less clear, however, whether such assistance would have enhanced or undermined her self-efficacy.

In her reflections, Brianna explained how the investments she made to teach Keith, like reviewing the Hummingbird website beforehand, and her willingness to take a dominant role, helped develop her knowledge and self-efficacy (i.e. confidence). Investments were also apparent in the recordings. During one Zoom session, Brianna asks her father how he connected two robotic components, indicating she showed the kit to him and leveraged his expertise (Brianna confirmed her father had prior robotics experience and experimented alongside her). Later in the session, she can be seen showing off her robot to her family with obvious pride (i.e. "Oh, y'all look. Look, Dad!"). These actions suggest that mastering the content was both motivating and rewarding for Brianna. Successfully building a robot can be seen as a mastery experience which likely contributed to her self-efficacy (Bandura 1997).

Theme	**Illustrative Preservice Teacher Reflection Statement**
Commitment to fifth grader's learning (emergent theme)	-The lessons purposes were to give the student a foundational knowledge and understanding of engineering and robotics and how the two coexist. I also wanted my student to come away with a sense of pride and confidence to plan and create something functional. -I saw so much of myself in him and I immediately knew that he was capable of anything…. I felt it was my duty to protect and push him to his fullest potential, to defy every odd.
Knowledge & Self-efficacy for Engineering/ Robotics	-Most of the ideas and delivery came from me. -My participation has definitely given me the confidence to try to tackle this Hummingbird kit completely and maybe move on to more advanced types of coding. -My willingness to learn something so far from my norm allowed me to understand that engineering and coding could become a part of my day to day life and was already a part of it.

Benefits - Autonomy - Future Opportunities	-Virtual WoW Club gave me more autonomy than in-person WoW Club. I was able to decide what I wanted my student to achieve, the methods of instruction, what topics I wanted them to explore, and how much time I wanted them to work on it. -[Keith] had to be a little more self-motivated [in the virtual context], especially when he became frustrated. -WoW Club gave many students, including myself, access to experiences previously unavailable. I would have never imagined using the tools, robotics, and software that I have used this semester…. This club makes me proud to be an educator and hopeful for the future generations. No matter how small the project is it still ignites a spark in everyone to gain knowledge. This quest that we are trying to set these kids on will make them innovators, inventors, and maybe heroes.
Challenges - Interacting with fifth grader -Interacting with engineering student	-...sometimes my student would get a little out of hand. -I feel least confident about how I incorporated the engineering student in the project. I like to move fast and be proactive so when I felt that my engineering partner wasn't moving at the same pace or catching up I decided to start making most of the decisions myself and just looping him in afterwards. I wish I had more time to help him mesh with the teaching portion more but I didn't want to be worrisome towards him or frustrate myself.

Table 1: Preservice Teacher Reflection Statements and Corresponding Themes

RQ3: What benefits and challenges did the preservice teacher report experiencing?

Autonomy was a major theme in Brianna's reflections, noting how the virtual context allowed her to make additional instructional decisions, such as how to structure the sessions (see Tab. 1). She also seemed to appreciate the challenge of tackling something "so far from my norm." She explained how engineering and robotics knowledge "ignites a spark" and provides opportunities for children and adults alike. Although numerous technical challenges were observed in the recordings, Brianna mentioned very few in her reflections, perhaps because she was so adept at overcoming them. Instead, she noted challenges interacting with teammates, including keeping Keith on track, and navigating Craig's passivity. Because the virtual context reduced participant interaction outside their teams, it magnified the importance of internal team relations. While the intimacy of Zoom sessions provided time and space for positive relationships to blossom, it also required team members to persevere through uncomfortable dynamics.

Discussion & Scholarly Significance

This case study explored the experience of one preservice teacher as she collaborated virtually with an undergraduate engineering student and a fifth grader to design and build bio-inspired robots in an adapted-to-be-virtual after-school technology club. Working with her engineering partner as part of Team Flower, the preservice teacher was able to adapt a multi-part robotics lesson to a virtual format and successfully deliver it to her fifth grader partner via Zoom. She demonstrated culturally responsive engineering pedagogical practices within the online lesson and reported appreciating the opportunity to learn new skills outside her norm. These findings suggest preservice teachers may be able to meaningfully contribute to, and benefit from, online engineering/robotics experiences. All three participants in Team Flower successfully engineered a bio-inspired robot indicating that hands-on robotics instruction is feasible in an online format, especially when conducted in very small teams or using one-on-one instruction. Furthermore, the lesson events and outcomes suggest that the preservice teacher and fifth grader benefited from engaging in online robotics activities together.

The findings from this study are limited by its focus on a single team in a specific context, but they can offer insight on preservice teacher participation in online robotics and engineering instruction, especially in this time when the COVID-19 pandemic continues to reshape education. The adaptation of Team Flower's robotics lessons to a Zoom-based virtual delivery modality impacted the lesson events and the preservice teacher's experiences in significant ways. Conducting a hands-on robotics lesson via a video conferencing tool made communication challenging, but forced the participants to develop creative solutions to sharing information and managing multiple applications simultaneously. This finding may be especially relevant for virtual instruction opportunities occurring in the context of instructional technology courses where preservice teachers are expected to learn how to leverage technology applications to best meet their students' needs. Distractions inherent to synchronous video-based instruction (e.g. pets and family) occasionally diverted the participants' attention away from lesson objectives, but also provided opportunities for relationship building. Preservice teachers could benefit from discussions exploring the ways these tools can foster social interactions within online learning environments.

The individual Zoom session format of the robotics lesson increased the autonomy, responsibility, and expectations of the preservice teacher. The preservice teacher was responsible for hosting the Zoom meetings for her team and expected to be present at all sessions. Perhaps motivated by this new role, Brianna invested time learning the robotics content and took the lead in planning and delivering the instruction. With continuous access to the robotic components, Brianna had more time to develop expertise and to leverage additional resources in her pursuit (e.g. family members). In her reflections, she discussed the increased autonomy she experienced as a result of the transition to virtual instruction, and expressed appreciation for the opportunity to structure the Zoom sessions as she saw fit and in accordance with the needs of her fifth grade partner. This autonomy may have also fueled her motivation to learn the content and skills associated with the lesson (Deci & Ryan 2012). Brianna's positive response to her experience teaching robotics online mirrors research on K-12 teachers' satisfaction with online teaching. Teachers tend to be more satisfied when they have flexibility in how they teach, when they are able to interact one-on-one with students, and when their efforts positively impact student performance (Borup & Stevens 2016). Brianna experienced all of these factors.

The findings shine a light on the role of autonomy in preservice teacher field experiences generally and demonstrate how autonomy support may contribute to self-efficacy (Kanadlı 2017). Brianna had the freedom to structure the sessions, but she also had her engineering partner and instructors available if she needed assistance. If preservice teachers feel personally responsible for delivering robotics content and helping a partner fifth grader succeed, they may be motivated to prepare for those experiences, and gain confidence when they achieve success. If their fifth grade partner is successful, this may be interpreted as a mastery experience and contribute to the preservice teacher's self-efficacy (Bandura 1997). Despite the reasonable logic of this conclusion, this research is limited by its focus on a single team's experience with a COVID-19 adaptation to teaching robotics. Brianna's dominance in the lesson, fueled at least in part by her personality, may have been a major factor in her outcomes. A future paper is planned to explore multiple teams' experiences.

A final purpose of this case study was to evaluate whether or not virtual WoW Club is a valid model that could be replicated, especially given the likelihood of continued virtual learning. The researchers acknowledge that significant resources were levied in order to shift this project online, including purchasing and delivering robotics kits for all participants, and that teaching robotics remotely has many challenges. However, the confidence and competence demonstrated by the preservice teacher, the positive influence of the virtual environment on her development, and the opportunity for preservice teachers to develop a new essential skill–teaching online via Zoom–suggests the approach is worth repeating.

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