Ed+gineering: Adaptations to COVID-19

Project Overview

The COVID-19 induced school shutdown dramatically decreased hands-on STEM learning opportunities for both K-12 and college students alike. Two interrelated NSF-funded programs partnering preservice teachers (PSTs) and undergraduate engineering students (UESs) to teach engineering lessons to elementary school students adapted their interventions to a virtual format to keep hands-on STEM instruction alive. The Ed+gineering effort at Old Dominion University (ODU) includes two NSF-funded projects, *A Service-Learning Partnership to Enhance Engineering Education and Elementary Pre-service Teacher Education for Undergraduate Students,* funded under IUSE (#1821658), and *Ed+gineering: An Interdisciplinary Partnership IntegratingEngineering into Elementary Teacher Preparation Programs* (#1908743), funded through DRK-12. Ed+gineering brings education and engineering students together to learn from and with each other, as they plan and deliver engineering lessons to 4th and 5th graders as an integral part of their respective preparation programs. The project involves three collaborations between the two groups of students: Collaboration 1 between PSTs in their first education course and freshmen engineering students; Collaboration 2 between PSTs in an educational technology course and engineering students studying computing and mechanisms; and Collaboration 3 between education students enrolled in elementary science methods and engineering students studying fluid dynamics.

While the IUSE and DRK12 projects are complementary and synergistic, there are clear distinctions. IUSE targets both populations of undergraduates, while DRK12 focuses exclusively on the PSTs. The primary goal of IUSE is to develop undergraduate students' engineering and science knowledge, whereas DRK12 focuses on the pedagogical knowledge and attitudes PSTs need to integrate engineering into their instruction. IUSE also investigates how the collaborative partnerships between PSTs and UESs enhance students' professional skills. Meanwhile, DRK12 investigates the experiences and support PSTs need to bring engineering instruction into their future P-6 classrooms.

Project Interventions in a Pre-Pandemic World

Prior to school site closures, all three Ed+gineering collaborations were in full swing. In Collaboration 1, small teams of 4-6 PSTs and UESs had just completed a trial run of the engineering lessons they had designed for 5th graders who were planning to come to the ODU campus for Engineering Day, an all-day field trip where the elementary students tour residence halls, engineering labs, eat lunch in a university dining commons, and participate in the hour-long lessons planned by the collaborating PSTs and UESs. The inquiry-based lessons followed the 5E instructional model (Engage, Explore, Explain, Extend, Evaluate) and focused on an engineering design challenge: either designing an air drop package or designing the blades for a windmill. In Collaboration 3, which follows a similar field trip model to Collaboration 1, small teams of PSTs and UESs had recently visited the classrooms of the 4th graders for whom they were designing lessons. In order to develop culturally responsive lessons connected to the children's interests, the undergraduates prepared presentations on 12 different fluid dynamics-related topics, such as slime, cooking, and military jets. After the class demonstrations, the children were encouraged to select their favorite three topics and the undergraduates had just begun planning their lessons based on the 4th graders' preferences in anticipation of their scheduled visit to campus for the Collaboration 3 Engineering Day.

Collaboration 2 follows a different model where, starting the 5th week of the semester, the PSTs run an after-school technology club for 5th graders during their weekly class meeting time. One of the club projects is to design, build, and code a bio-inspired robot that can address a global challenge. To prepare to lead this project the PSTs work with an engineering partner to collaboratively learn basic block coding and experiment with a few simple mechanisms. At the time of the shut down, the PSTs had already built simple robots with their engineering partners and held four club sessions with the 5th graders, but they had not yet started the robotics project with the 5th graders during the club sessions.

Spring 2020 Adaptation Plans

When the school sites closed in March, the Engineering Day field trips were cancelled and the after school technology club could no longer meet in person. Rather than terminating all three collaborations mid-stream, the Ed+gineering project team made the decision to adapt the activities to virtual learning experiences. For Collaborations 1 & 3, instead of planning and teaching live lessons to elementary students who would visit the campus, the teams of collaborating education and engineering students were asked to create asynchronous virtual lessons using Google Slides. The teams ensured that all suggested materials required for elementary students to participate in their engineering lessons could be found around most homes. Teams collaborated via Zoom (or similar technology) to plan their lessons, and to generate multimedia (i.e. audio and video recordings) to supplement their google slideshows. This was an ambitious task, as using technology to collaborate and create multimedia content was new to many students. To facilitate this process, an exemplar and template were created by the course instructors to help guide student products.

In Collaboration 2, the after-school technology club was moved online and took the form of 19 simultaneously occurring weekly Zoom meetings over the course of 4-5 weeks. Each PST was responsible for hosting a meeting for her/his engineering student and 5th grade partner. The instructors delivered Hummingbird robotics kits to each participating PST, UES, and 5th grader. Instead of sharing one kit and collaborating on a single team robot as had been done in the past, each participant was encouraged to build their own robot based on their team's chosen theme.

Spring 2020 Adaptation Outcomes

All nineteen teams of students in Collaboration 1 produced a virtual engineering lesson. These lessons were distributed to the classes who were planning to attend the Engineering Day field trip as well as other interested teachers. Elementary school students were encouraged to participate though a raffle/contest to win engineering-related toys. Eighteen students submitted a contest entry; the great majority of these came from one teacher who offered her students extra credit to complete the project. To our knowledge, none of the teachers who received the engineering lessons attempted to use them during a synchronous class meeting with their students. At this time, most local schools were providing few synchronous learning opportunities, and many teachers and students were inexperienced with online teaching and tools, and feeling overwhelmed. There were prizes (gift cards) awarded to the ODU student teams who produced the best lessons, as an added incentive beyond their grade on the project. The winning team's visually appealing lesson made clever use of bitmojis to represent its five team members and clearly presented the design challenge and related concepts. The instructors followed up with most teams multiple times to ensure all virtual lessons were classroom ready. Many of the follow-ups focused on sharing permissions for the multimedia content, although some teams needed additional guidance to create effective and appropriate content.

The seven teams participating in Collaboration 3 each produced a virtual lesson specifically designed to address the interests expressed by its intended 4th grade audience. For example, two teams designed challenges based on water parks. These culturally responsive lessons were delivered to the seven teachers of the 4th grade classes, all of whom were working in Title I schools. As with Collaboration 1, few students interacted with the lessons, largely because teachers were unable to equitably provide synchronous online instruction to the students, and most teachers were encouraged to use district-produced packets as the instructional material for the students.

In Collaboration 2, nineteen teams, each consisting of one education, one engineering, and one 5th grade student, produced at least one bio-inspired robot. Many teams produced three robots, one by each participant. Each team's robot(s) was/were built over the course of 4-5 Zoom meetings (~two hours/meeting). In total, 65 robots were engineered. Each team produced a "shark tank"-style pitch to explain and promote their robot and these were shared via a Google form to compete for an audience choice award (a Hummingbird kit) and presented during a virtual family showcase event. A representative from Birdbrain Technologies, the maker of the Hummingbird kit, also awarded prizes during the showcase, adding industry credibility to the recognition students received for their efforts.

Research & Dissemination Efforts

To assess the outcomes of the Ed+gineering collaborations, the project team leverages surveys, objective tests, student reflections, and focus group interviews and answers research questions focused mainly on how students' knowledge and attitudes have changed based on their participation. The Spring 2020 COVID-19 adaptation allowed the researchers to examine a new data source: lesson artifacts. Collaboration 1 & 3 produced 26 digital lessons (i.e. multimedia Google slideshows). Collaboration 2 resulted in approximately 60 recorded Zoom sessions. These rich qualitative sources provide an in-depth picture of the participating undergraduate students' teaching and learning.

A journal paper is planned to analyze the impact of the COVID-19 intervention on the participants of Collaboration 1 & 3. A manuscript reporting on the results of the Collaboration 3 intervention has already been submitted to an educational research conference. The research on Collaboration 3 examined the virtual lessons produced by the teams in conjunction with the original data sources to explore the following research questions:

1. How did the COVID-19-induced transition to remote learning affect the experiences of PSTs and UESs in the project?
2. How did teams adapt to use appropriate technological and pedagogical strategies to support engineering lesson task completion for elementary students in a virtual environment?
3. How did teams develop and implement culturally responsive virtual elementary engineering lessons? How did an initial school visit contribute to teams' creation of virtual lessons that were culturally responsive?

The PSTs who participated in Collaboration 2 were asked to record their Zoom meetings. These meetings provided a unique opportunity to witness the teaching and learning of the PSTs and UESs as they interacted with their 5th grade partners to engineer their robots. This rich data source is enabling a qualitative examination of the virtual robotics lessons and the resulting impacts on PSTs' knowledge and beliefs. Research on multiple teams is planned for a journal article, but to date a case study has been written and submitted to a national educational conference that provides a detailed description of one team's experience. The paper aimed to uncover what happened during the multi-part lesson and how the experience affected the PST. Two research questions guided the investigation, the first being intentionally broad to encompass both planned (e.g. EDP) and unplanned (e.g. family interactions) events.

1. What occurred during the team's virtual Zoom sessions? How did the virtual context shape lesson strengths and challenges?
2. What benefits and challenges did the PST report?

In addition to the submitted conference manuscript describing one team's experience, the team also produced a video compilation of another team's experience. A 3-minute video showcasing excerpts from Team Dolphin's experience engineering robotic dolphins was submitted to the National Science Foundation (NSF) sponsored STEM DIVE (Diversity and Inclusion Video Exhibition) Challenge. The video chronicled the team's effort over four sessions and can be viewed here: https://youtu.be/DXT6P5lE2G8. (A slightly longer 4-minute version that includes a description of the origin of the project was shared during an ASEE presentation.)

Summary of Research Findings

A brief summary of the research findings related to Collaboration 3 and 2 are shared below:

Collaboration 3 (Mixed method analysis of undergraduate teams' online shift to teach elementary engineering lessons)

Generally speaking, students participating in Collaboration 3 found that their team collaboration and productivity remained consistent even following the shift to remote learning. However, some students did share negative impacts on team communication (e.g.,"Switching to online only was the worst thing that would have happened, if I'm being honest.") and productivity (e.g., "The overall work ethic was already low, but dropped even further for other group members."). Positive comments focused on the opportunity to use different media (e.g., "...examples, pictures, and even videos that the students could watch and see…") and an impression that other extracurricular aspects of students' lives slowed down and allowed more room for their academic work. Many students expressed frustration about having to change the structure and pedagogy of their lesson to ensure student engagement and learning in the virtual environment.

In their lessons, the cross-disciplinary teams utilized various technological tools such as embedding personal voiced audio clips (100%) and video recording (43%) to connect with students to introduce themselves, content, and/or procedures. Teams also utilized web-based virtual tools to provide opportunities for formative assessment (e.g., Padlet, Google Form, Kahoot). General preK-6 pedagogical strategies were observed throughout, such as use of age-appropriate vocabulary and definitions, and probing questions. The researchers also identified areas for improvement within the lesson presentations, including the need for a reduction in text on slides, and an increase in interactive tools to further engage and motivate students.

Participants seemed to develop an appreciation for the importance of culturally responsive pedagogy. In their reflections, they often expressed the importance of designing lessons that align with elementary students' interests, including place-based examples of real-world engineering that students could relate to, and representing engineering professionals who may look like (e.g., race, ethnicity, gender) the students in their assigned class. The preliminary visit to the 4th graders' schools proved to be highly influential in the development of the lesson. Teams often said they were assured that 4th grade students would enjoy the selected engineering topic because they gave the students input via their topic survey, and because they had taken into consideration what the 4th graders already knew about the topics. Team members also valued the opportunity to develop relationships with the kids and learn more about ways in which to keep students engaged (e.g., hands-on activities, classroom management strategies).

Collaboration 2 (Case study of one PST's experience teaching a multi-part virtual robotics lesson via Zoom)

RQ1: What occurred during the team's virtual Zoom sessions? How did the virtual context shape its strengths and challenges?

Some strengths and challenges were consistent throughout the lesson series. For example, the team was repeatedly challenged by limited bandwidth and geographical distance. Relying on webcams and screen sharing to identify problems and communicate solutions, it was not always easy to hear team members, see what they were doing, share resources (e.g. YouTube), and navigate multiple technology platforms and applications. With time, the team's adaptations to the virtual environment became more innovative (e.g., the PST connected to Zoom on one device and edited their video on another). Although the researchers observed excellent use of educational technology, and multiple tools were leveraged to support collaboration and produce lesson artifacts, some issues remained unresolved. For example, the 5th grader's servo motor stopped working in session three, and never regained functionality.

The virtual context amplified the already informal context of the club, with pets, family members, and silly antics creating diversions. These "diversions" took the team off-task, but created opportunities to build rapport. The 5th grader was repeatedly observed trying to impress the PST, and the two often teased each other affectionately. The relationship between the 5th grader and the PST often seemed to drive the lessons and clearly served as a motivating factor for both students.

The PST demonstrated confidence and competence presenting engineering/robotics content, dominating both lesson planning and delivery. However, there were multiple opportunities where engineering/robotics content could have been introduced and/or explored with greater depth. Had the engineering student played a larger role, the instructional level may have increased, and specific hardware issues may have been able to be resolved. While the isolation of the Zoom teaching environment expanded PSTs role, it decreased opportunities for assistance from other participants with engineering expertise.

In her reflections, the PST explained how investments she made to teach her 5th grade partner, like reviewing the Hummingbird website beforehand, and her willingness to take a dominant role, helped develop her confidence and competence. Other investments were also apparent. During one session, the PST asks her father how he connected two robotic components, indicating she showed the kit to him and leveraged his expertise. Later in the session, she can be seen showing off her robot to her family with obvious pride. These actions suggest that learning the content was both motivating and rewarding for her.

RQ2: What benefits and challenges did the PST report experiencing?

Autonomy was a major theme in PST's reflections, noting how the virtual context allowed her to make additional instructional decisions, such as how to structure the sessions. Although numerous technical challenges were observed in the recordings, the PST mentioned very few in her reflections perhaps because she was adept at overcoming them. Instead, she noted challenges interacting with teammates, including keeping the 5th grader on track, and her engineering partner's passivity. Because the virtual context reduced participant interaction outside their teams, it magnified the importance of internal team relations. It provided time and space for positive relationships to blossom, but also required team members to persevere through uncomfortable dynamics.

Fall 2020 & Spring 2021 Implementations

The Ed+gineering project team is running comparison groups for the Fall 2020 semester and using the time to analyze and synthesize the additional data collected in Spring 2020. The plan is to implement virtual lessons again in the spring if K-12 restrictions on field trips and after-school clubs are not lifted. If the local elementary schools resume in-person teaching, it may be feasible to plan for synchronous online lessons, which the team is hoping will be able to reach more children than we reached with the asynchronous lessons produced in Collaborations 1 & 3 in Spring 2020. The data from the spring has made clear the powerful impact the interaction with K-12 pupils has on the undergraduate students' learning experiences. The team is planning to ensure that interaction can occur, even if it is via webcams.

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