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Article

Exploring How Secondary STEM Teachers and Undergraduate Mentors Adapt Digital Technologies to Promote Culturally Relevant Education during COVID-19

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Abstract: The COVID-19 global pandemic presented unprecedented challenges to K-16 educators, including the closing of educational agencies and the abrupt transition to online teaching and learning. Educators sought to adapt in-person learning activities to teach in remote and hybrid online settings. This study explores how a partnership between middle and high school teachers in an urban school district and undergraduate STEM mentors of color leveraged digital tools and collaborative pedagogies to teach science, technology, and engineering during a global pandemic. We used a qualitative multi-case study to describe three cases of teachers and undergraduate mentors. We then offer a cross-case analysis to interpret the diverse ways in which partners used technologies, pedagogy, and content to promote equitable outcomes for students, both in remote and hybrid settings. We found that the partnership and technologies led to rigorous and connected learning for students. Teachers and undergraduates carefully scaffolded technology use and content applications while providing ongoing opportunities for students to receive feedback and reflect on their learning. Findings provide implications for community partnerships and digital tools to promote collaborative and culturally relevant STEM learning opportunities in the post-pandemic era.

Keywords: collaborative technologies; community partnerships; STEM education; COVID-19; middle school; high school; culturally relevant pedagogies

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1. Introduction

The COVID-19 global pandemic presented unprecedented challenges to K-16 educators, students, and parents, including the closing of educational agencies and the abrupt transition to online teaching and learning. Educators navigated uncharted waters as they sought to adapt in-person learning activities to teach in remote and hybrid online settings. The pandemic created challenges for teachers and students, especially those in under-resourced school contexts where there are fewer structural supports to accommodate the pressing needs faced by historically marginalized communities and students of color, namely Black, Hispanic, and Latinx students [1,2]. Even before the pandemic, educational researchers warned that digital media could be contributing to inequities in education and pointed out "a growing gap between the progressive use of digital media outside of the classroom, and the no-frills offerings of most public schools that educate our most vulnerable populations" [3] (p. 7). COVID-19 forced schools across the world to address the complex challenge of facilitating remote learning in ways that did not widen the equity gap.

Despite the challenges faced by students in under-resourced schools, policy leaders encouraged teachers to adapt content quickly and maintain high-quality instruction to account for the likelihood of learning loss [4]. As a result, district administrators provided educators with an overwhelming abundance of online curricula and instructional technologies with variable guidance on using these materials. While scholars have detailed the promise and potential of digital technologies in K–12 schools [5,6], integrating technology into pedagogical practices that promote student-centered and connected learning has proven to be challenging for teachers [7–11]. One way that STEM teachers can promote authentic connections to learning for students of color is by positioning Black and Brown professionals as mentors in the classroom [12]. Culturally relatable mentors show promise for developing the academic, social, and cultural capital of students of color, supporting them to see themselves in STEM fields [13]. This study explores a partnership between middle and high school teachers in an urban school district and undergraduates in STEM fields who sought to reimagine online learning to include opportunities for collaboration, cultural relevance, and critical thinking for secondary students during COVID-19. Specifically, we examined the following research question: How do middle and high school teachers leverage virtual collaborations with STEM undergraduate mentors and use digital technologies to promote equitable learning experiences for students during a global pandemic?

1.1. Collaborative Technologies to Promote Social Connections and Culturally Relevant Education

Digital technologies have transformed how youth communicate and interact in the 21st century. For example, young people are changing what it means to be civically engaged through participation in networked communities like #BlackLivesMatter, the Harry Potter Alliance, and the DREAMer movement [14]. This kind of digitally-mediated learning can be considered *connected learning*, that is, "learning that is socially embedded, interest-driven, and oriented toward educational, economic, or political opportunity" [3] (p. 4). Connected learning happens when young people can pursue their interests and passions with the support of peers and caring adults and can link that learning to academic achievement, career possibilities, and civic engagement [3]. In this way, connected learning can be seen as a tool to promote equity as it aligns with the tenets of culturally relevant pedagogies. These tenets include connecting students' cultural references and funds of knowledge to academic skills and concepts, engaging them in critical reflection about their own lives and societies, facilitating cultural competence, and explicitly unmasking oppressive systems through the critique of discourses of power [15,16].

While digital technologies show great promise for connecting students to learning, many science and mathematics classrooms in urban schools are still characterized by traditional forms of instruction and have been criticized for not effectively preparing marginalized youth to pursue STEM careers [17]. The standardized curriculum in mathematics and science courses within K–12 schools is largely disconnected from the lives of students of color [18]. STEM culture and curriculum have been dominated by Eurocentric ways of knowing, which marginalizes the contributions of scientists and engineers of color and serves as a barrier to students of color pursuing STEM courses and careers [19]. Limited social and cultural capital represents another barrier to underrepresented students' pursuit of careers in STEM [20]. Nevertheless, there are opportunities to leverage digital technologies to promote more culturally relevant pedagogies within STEM classrooms. Digital technologies can serve as a mediator between social justice, STEM, and equitable outcomes for students [21]. For example, media, editorials, and historical narratives can situate scientific and mathematical problems in socio-political contexts and provide a lens for critically analyzing data [22,23]. Further, digital technologies can supplement standardized curriculum and provide various modes of content representations and literacies that support students of diverse languages and abilities [24,25]. Digital technologies can also provide students with opportunities to develop essential practices necessary for STEM learning, such as research skills, concept mapping, collaborating with others, and communicating explanations and solutions [26,27].

1.2. Digital Notebooks

Helping STEM teachers use digital technologies that promote social interaction and cultural relevance for students is a complex challenge, arguably more so within the context of COVID-19 education when teachers did not have a choice in adapting to online instruction. The use of technologies in the classroom should be carefully aligned with appropriate content and pedagogies that consider the social practices of culturally and linguistically diverse students [9,28]. Further, for teachers to adopt technologies quickly and use them appropriately, the tools need to have an element of familiarity and present an advantage for teachers to adopt them in practice [29–31]. Digital notebooks have been studied most prevalently in the context of science and engineering, as they adapt the familiar science notebook to provide a collaborative space for students to explore scientific phenomena and define problems, document research, ideate sketches, display data, and communicate and interpret results [32,33]. Digital notebooks have the potential to provide engaging opportunities for students to document their learning through traditional methods such as uploading photographs of drawings and models as well as incorporating research links, images, audio recordings, videos, and cloud-based drawing tools [34]. These notebooks have supported concept development and mechanistic reasoning for elementary-aged students, in particular [35–37]. Scholars and practitioners have pointed to Google applications as a practical tool for creating and sharing curriculum and differentiating content for students [38]. More than half of middle school teachers across the United States report using the Google apps platform [38]. Google apps are cost-efficient, convenient, and accessible to administrators, teachers, and students [39]. This study explored how teachers adapted a digital notebook constructed using Google Slides to connect students with science, technology, and engineering content and processes.

1.3. Collaborating with Undergraduate STEM Mentors

Strategic virtual partnerships between teachers and professional mentors of color show promise for presenting equitable learning experiences for underrepresented students in STEM. In an exploratory case study of an online community of practice between professional engineers, middle school teachers, and their students, Kier and Khalil found that digital technologies supported stakeholders to communicate personal and professional connections to K–12 content, build mentoring relationships, and broaden awareness of STEM careers for marginalized students [21]. Logistically, the schedules of STEM professionals are difficult to align with those of teachers [12]. However, scholars have pointed to undergraduate mentors of color as resources for supporting underrepresented students to pursue and persist in STEM [40,41]. The relationships and knowledge gained from close interactions with undergraduate mentors of color may grant students of color access to critical information, or capital, that they may not otherwise receive in standardized academic STEM classrooms [13]. Because undergraduates are still building their repertoires of practice [42], they are more proximal to middle school students in terms of their development; this proximity can help facilitate learning within a community of practice with middle school teachers and students [43]. While there are many positive outcomes associated with mentoring relationships in STEM, little research has examined how undergraduate mentors have used digital technologies to collaborate and communicate with students. The shift to remote learning provided a unique opportunity to explore how teachers, undergraduate mentors, and students used digital technologies to support collaboration and communication.

2. Materials and Methods

This qualitative research study explores the question: How do middle and high school teachers leverage virtual collaborations with STEM undergraduate mentors and use digital technologies to promote equitable learning experiences for students during a global pandemic? Because this study was part of a larger exploratory grant investigating the roles in which secondary teachers and STEM undergraduate mentors assumed when teaching the engineering design process (EDP), we will describe our context, partnership, and adaptations for COVID-19. Additionally, we will describe our data collection and analytic techniques.

2.1. Context

This study took place within a large urban school district in the mid-Atlantic region of the United States. Approximately two-thirds of the student population in the district qualify for free or reduced lunch, and all students receive free lunch due to COVID-19. Student demographic data, as reported to the State Department of Education, show that the majority of students are students of color; specifically, 54% identified themselves as Black or African American, and 13% identified as Hispanic, Latino or Spanish Origin. This school district has had a long-standing research–practice partnership with the affiliated institution of the two authors. In 2019, the first author, a teacher and research scholar of science education was awarded a federally-funded grant in collaboration with the STEM professional development coordinator of the district. Through this grant, we sought to explore how undergraduate STEM majors of color might support students, particularly Black, Hispanic, and Latinx students, to see themselves in STEM when partnering directly with STEM teachers in classrooms. The STEM professional development coordinator saw partnering with undergraduate mentors of color as a unique opportunity for "STEM teacher leaders" in the district. STEM teacher leaders are science, mathematics, or computer science teachers who apply each year to pilot STEM initiatives in their classrooms and lead professional development with their colleagues and students. The building administrator selects one STEM teacher leader per school in each elementary, middle, and high school. Once chosen by district administrators, the district compensates STEM teacher leaders. They attend professional developments and implement innovative strategies, technologies, and curricula in their classes.

Thirteen middle and high school STEM teacher leaders agreed to participate in professional development, classroom implementation, and research as part of their STEM leader responsibilities. In addition to the incentives provided to them through the district, the grant provided them with an additional stipend and project supplies for their classrooms. Each of these teachers was paired with an undergraduate STEM major recruited from local university chapters of the National Society of Black Engineers (NSBE). The undergraduates were given a stipend for their participation in the project and were matched with a teacher who taught classes related to the undergraduates' area of expertise. The teacher–undergraduate pairs met with the researchers (both authors on this project) and the STEM professional development coordinator in five afterschool planning meetings prior to classroom implementation to identify a science or mathematics topic within their curriculum that could be taught through the EDP. The professional development coordinator asked teacher–undergraduate pairs to integrate their content into an engineering design challenge for students using an adapted model of NASA's Beginning Engineering, Science and Technology engineering design process [44]. This process asks students to define a given problem, brainstorm solutions and research ideas, create prototypes, collect data and evaluate results, revise the solution, and justify their design decisions. Teachers and undergraduates were also shown examples of engineering design challenges that had been implemented by teachers in the past, including projects on designing a mechanical hand, solar-powered cars, and robots that performed diverse functions. We analyzed teacher–mentor conversations as well as the roles that the undergraduate and teacher assumed during classroom implementation. We found that undergraduates showed promise for promoting a more culturally relevant approach to engineering and supported teachers to create engineering design challenges that focused on the needs of individuals and communities (e.g., creating a device that will sort recyclable and non-recyclable materials; redesigning the blueprints of a school that was about to close in the district) [45]. We also found that culturally relevant education opportunities occurred when teacher partners had a student-centered philosophy to teaching STEM, when teachers positioned mentors as prominent figures in their classrooms, and when teachers and undergraduate mentors approached engineering through a humanistic and socio-political lens [45]. Unfortunately, in March of 2020, the partnership and instructional activities were halted because of the

COVID-19 pandemic; most students never had the opportunity to evaluate their designed prototypes, as they abruptly shifted to remote learning.

2.2. Adaptation of the Partnership to Include the Digital Engineering Design Notebook

The authors and the school district's STEM professional development coordinator came together in the summer before the academic year 2020–2021 to adapt the partnership model for a COVID-19 educational context. We considered ways to engage students in the EDP while using virtual collaborations with STEM undergraduate mentors in both remote and hybrid online learning spaces. Further, we recognized that for teachers, undergraduates, and students to participate in the project during this time, they would need a clear organizational structure and exemplary models. Additionally, the district placed significant emphasis on students' reading skills during this time and encouraged teachers to focus primarily on literacy development. The expertise of Author 2 was essential to conceptualize digital tools and opportunities to build literacy skills during the EDP. As an English teacher educator and scholar of digital literacies, Author 2 led the design of the digital engineering design notebook (hereafter called the engineering design notebook); this tool provides an interactive approach to using the technology of Google Slides where students can document their reflections and design decisions. The engineering design notebook promotes collaboration between students and undergraduates, as students receive feedback during each stage of the EDP directly in Google Slides. Using digital technologies for timely online feedback and redirection by mentors during the EDP can support students' deeper learning and application of academic concepts and skills [46]. The engineering design notebook also includes space for students to create visual representations of their models by uploading drawings or using online sketching programs like Google Draw. Each section of the notebook was aligned with the stages of the EDP [44], with clear objectives for each stage.

All STEM teacher leaders at the secondary level were invited to the partnership with a mutual understanding among district administrators and the university researchers (authors) that the fidelity of implementation may look different than conceptualized. The virtual nature of the partnership with undergraduate STEM majors presented the opportunity to expand our recruitment of undergraduates to NSBE chapters across the state. Eight secondary teachers at the middle and high school level committed to participating in the implementation research project. Teachers and STEM undergraduate mentors were paired based on similar content backgrounds. For example, one undergraduate who majored in conservation engineering was paired with a middle school teacher who taught marine biology. As teacher education researchers, we took a flexible approach to the partnership, ensuring teachers and undergraduates that we would support them through implementation. All teachers and undergraduates were provided again with monetary incentives and supplies to participate. Further, undergraduates received personalized recommendation letters from Author 1 following their participation in the partnership.

Through virtual Zoom meetings with teachers and undergraduates, we demonstrated how teachers could implement two engineering design challenges using the engineering design notebook. We modeled one challenge that focused on water pollution and one on a rescue mission to deliver food to people in need during a natural disaster. We explained to teachers how to integrate pedagogical literacy strategies within the engineering design notebook for students to demonstrate their understanding of the EDP and academic concepts. For example, we incorporated examples of reading comprehension instruction to help students understand multi-modal texts [47]; explicit vocabulary instruction [48]; and writing to learn activities [49]. We showed teachers how to include writing to learn techniques such as annotating texts, documenting and sharing plans, models, and data, and providing written feedback to peers within their engineering design notebook. We met with all teachers and undergraduates monthly to discuss ideas and troubleshoot any challenges that arose during implementation. During these meetings, teachers also shared their ideas with each other and modeled sections of their notebook for others to leverage in their instruction.

In the academic year 2020–2021, K–12 teachers across the district began the school year remotely and used a video teleconferencing software program (Zoom) to provide synchronous online instruction for students. Students who lacked access to the internet were provided with individual hotspots, and Chromebooks were provided to every student to reliably participate in academic learning. Teachers also used the learning management system (LMS), Canvas, to communicate with students, and to provide activities and assignments in a clear and modularized format to help scaffold student learning. In January of 2021, students chose to continue learning from home or come to school two days a week while engaging in asynchronous online learning during the other days of the week.

2.3. Participants

As mentioned previously, eight teachers agreed to participate in the partnership and project in 2020–2021. However, only four of the teacher–undergraduate pairs, three working in middle schools and one in a high school, completed an entire engineering design notebook with an undergraduate mentor, facilitated the entirety of the EDP, and submitted student work to the research team. The teacher–undergraduate pairs who were unable to complete the requirements identified time, scheduling, other professional commitments, and students' immediate needs during COVID-19 as factors that impacted their participation in the project.

We focused our study on three of the teacher–mentor pairs who completed the project activities. It is important to note that a key factor in the teachers being able to implement this project was likely due to the fact that they taught STEM courses that did not have a state standardized assessment at the end of the course. This course structure, then, provided them a degree of freedom and flexibility not available to teachers who taught courses that required that students cover a great deal of content in order to meet the competencies found on the end-of-course state assessment. Three teacher–undergraduate pairs were selected because they showed three distinct examples of disciplinary content being taught (e.g., marine science, anatomy, and computer science), and completed the activities with students during school; the fourth teacher–mentor pair who conducted their challenge completed the activities during an afterschool club online. Through these cases, we examined the strategies that the pairs enacted for collaboratively planning and implementing engineering with students, and how they used digital technologies in the process. We specifically looked for ways in which the teacher–undergraduate pairs leveraged opportunities for culturally relevant education in remote and hybrid settings. Table 1 provides the backgrounds of the teacher and undergraduate mentor, the engineering design challenge that they facilitated, and the class in which they decided to implement the challenge.

Table 1. Descriptions of teachers, undergraduates, engineering tasks, and class.

Teacher	Undergraduate STEM Mentor	Engineering Design Task	Class
Milania Black female First-year teacher; previously had a career as a mechanical engineer	Donte Black male Aviation major Third year; junior	Design and code a functioning human-like hand	Homeroom class that met synchronously online every Friday; 10 high school advanced physics students
Elliot White male 16 years of teaching experience	Michelle Black female Biological systems engineering major Fourth year; senior	Design a transport system that carries water from a local river, filters it, and delivers it to individuals in a fictional town that faces water insecurity	Marine science class delivered in person and synchronously online; 20 sixth-grade students
Willow Black female Second-year teacher; previously had a career as an instructional technology specialist	Brielle Black female Computer engineering major Third year; junior	Design and code a song that focuses on racial equity and entrepreneurship	Computer science class delivered in person and synchronously online; 20 sixth-grade students

2.4. Data Collection and Analysis

We used a qualitative multiple case study [50] to describe three cases of STEM teachers partnering with STEM undergraduate mentors. Each teacher–undergraduate mentor dyad was in different schools, all of which reflected the demographic representation of the district at large. Each dyad also focused on different STEM subject areas and created distinct engineering design tasks. We considered each teacher–undergraduate mentor dyad one case because each dyad took specific approaches to making their partnership work virtually and engaging students in engineering opportunities through digital technologies in remote and in-person settings. We collected and analyzed two primary sources of data: semi-structured pre–post interviews and the engineering design notebooks (document analysis). We conducted interviews with teachers prior to beginning implementation to learn about their approach to STEM teaching and learning and their experiences teaching with engineering design challenges and digital tools. We also interviewed undergraduates who were interested in participating in the partnership to learn about their early experiences with STEM, their perceptions of effective teaching strategies in engineering, and what they hoped to gain through their participation in the project. We conducted interviews with both teachers and undergraduates at the end of the academic year to understand the benefits and challenges of the partnerships and how they used digital tools including the engineering design notebook to facilitate the partnership. We also asked both teachers and undergraduate students to describe recommendations that they had for others who might conduct similar projects in the future. We reviewed bi-weekly logs completed by teachers and undergraduates through the academic year to identify challenges faced at each stage of the project. We then engaged in a narrative-based descriptive approach [50] to reflect participants' voices and stories, applying descriptions from the engineering design notebook and detailing the roles of the teachers, undergraduates, and students. We first discuss the three individual case studies and then provide a cross-case analysis [51] to offer implications and recommendations for using virtual mentoring and digital technologies to promote collaboration and culturally relevant educational opportunities during remote online learning.

3. Results

Below, we describe the cases of Milania and Donte, Elliot and Michelle, and Willow and Brielle. For each case, we discuss how the partners adapted content, pedagogy, and technology, including the engineering design notebook, to promote collaboration and culturally relevant STEM experiences for students.

3.1. Milania and Donte: Building Classroom Community around Science and Engineering

Milania was a former mechanical engineer who switched careers to become a high school physics teacher. As a second-year teacher during the pandemic, she saw collaborative projects as an opportunity to give students hands-on experiences, "a voice" in their learning, and support "critical thinking." In her interview, she put forth that teachers should "see where students' imagination takes them, and hold them accountable for their own learning." Milania was paired with Donte, a third-year aviation major. Donte had been interested in engineering since elementary school, enjoying Legos, and even participating in design challenges in a NSBE summer camp as a middle school student. He took robotics classes in high school and developed his passion for aviation because his mother worked in an airport, and he spent a great deal of time with her. Donte hoped that through this collaboration, he could engage students during a time when they needed it most. When Donte was interviewed prior to his participation in the partnership, he described his desire to engage students who may be challenged by online learning during COVID-19. He stated,

> [I want to do] a project that virtually anybody could do from their own homes, no matter their background and also try to gear it towards the kids. I want to make it more fun, with interactive videos, kind of like, you know, kids are usually on Tik Tok and those apps, so kind of shift it to bring it towards their medium so that they're interested. I know being online and stuff sitting at home for hours and hours on end, watching people talk to you and explaining stuff is not probably the funnest way to learn. So really trying to adapt to them so that they could be interested in trying to retain information.

After Milania and Donte agreed to participate in the project, the first author sent an email introducing them to each other and provided them with dates for monthly planning meetings. Donte emailed Milania several times at the beginning of the school year but did not receive communication back from her. Through the bi-weekly Google Forms that we used to monitor progress, we confirmed that Milania had not reported any progress nor communication with Donte. We met with the STEM professional development coordinator to see if Milania needed any support to initiate the partnership and project with Donte. The STEM professional development coordinator reached out to Milania and offered her support for setting up an engineering design notebook and identifying content that could be situated within the engineering project. Milania graciously accepted the support and with the professional development coordinator, recognized an opportunity to enrich her advanced high school physics students in an engineering design project of a mechanical hand. This level of support provided Milania with confidence to reach out to Donte and share her idea for building a mechanical hand. Despite beginning the project later in the academic year than intended, Milania and Donte began to meet regularly through Zoom and reported weekly feedback to the researchers. Donte enthusiastically recalled his first individual Zoom meeting with Milania and stated,

> She told me kind of all about each student, um, kind of their personality traits because she'd been with them for almost the whole year. she spoke highly of each and every student. She gave me a rough idea of what each student's interests were.

Milania and Donte constructed an engineering design task and adapted curricular learning activities to be taught virtually through the engineering design notebook. They introduced this problem at the beginning of the engineering design notebook; it stated,

> With the rise in advancements in technology, the scientific community has challenged themselves to create artificial mechanical limbs to help increase the quality of life for individuals. These artificial limbs have proved to be useful, yet the hand remains a challenge as no mechanical limb has yet to reach its full potential,

> as it is either too big and clunky, doesn't move with a full range of motion, or looks too robotic and less human. Our goal is to work on fixing the problem of un-human-like artificial limbs to help assist those in need of them by researching, designing, and programming our own hand design.

Donte reflected that the pair may have "bit off more than they could chew" but he "loved Milania's energy" and he could tell that she "loved her kids." Milania and Donte decided to facilitate learning activities together during her homeroom period. This class met synchronously online every Friday at 7:00 am, and consisted of ten 10th–12th-grade students. Milania shared in an interview that she saw this period as a time to provide enrichment for her small group of physics students and an opportunity to "step behind the scenes and let the college student and the high school students come together".

Donte and Milania developed clear objectives for students to accomplish each Friday associated with each stage of the EDP (e.g., define the problem through research; find examples and images of past medical solutions). Milania carefully modeled the structure of the notebook on the first day of the project, and each Friday, she would explain to students their intended learning outcomes. Donte noted that "the engineering design notebook provided structure for the whole idea." He also shared that Milania's role was "setting goals that we needed to accomplish and making sure everything that we could do was on track." Because all students in the district were familiar with the Canvas LMS, Milania inserted their weekly objectives, link to the engineering design notebook, and a Zoom link to facilitate convenient access to synchronous online meetings. Donte shared that he got to know students each week by asking them, "Hey, how's everybody doing? How are things going?" and learning about their interests over time. He continued, "students were shy at first," but over time "students would bring their two cents and bless the classroom with the knowledge that they found." He also designed his own personalized pages in the engineering design notebook, detailing his hobbies and interests, interesting facts about his major, and pictures of himself actively participating in the study of aviation. Milania and Donte took a whole-class approach to implement the EDP and the engineering design notebook. All ten students in the homeroom class contributed to the engineering design notebook synchronously online and held each other accountable for each stage of the EDP. This whole-class approach helped build classroom community. It enabled the students, undergraduate, and teachers to work from the same engineering design notebook, document questions, and brainstorm new ideas.

Both Milania and Donte guided students to individually research, design, and code a mechanical hand. Milania primarily used Zoom to clarify instructions for the whole group, build direct connections to students' lives, and scaffold questions to encourage class discussion. For example, in the brainstorming phase of the notebook, Milania asked students, "What can we do now that is different from the past solutions? Say you have an auntie, uncle, or sister who just lost their hand. What can we do to make them feel like they didn't lose their hand?" Donte noticed that, at times, Zoom presented a context that could "allow students to disengage" as many students would "turn off their cameras"; however, because of the small class size, when students were called upon, they would "open up and participate." Milania's students brainstormed and documented questions about the engineering problem in the notebook. Their engineering design notebook showed that students asked questions such as, "How can we develop a program to simulate an accurate range of motion for a proportional hand? and, "How does the human hand work?" Milania asked students to select a research question that they were most interested in and document their findings and sources. Small research teams of students met in breakout rooms in Zoom to research the anatomy and physiology of the hand, medical developments in prosthetics, and how other students have programmed hands. While students were researching, Donte and Milania would go into different breakout rooms to add to students' research findings and answer students' questions. Donte and Milania critically examined students' ideas and probed them to think about "the benefits and cons" of each solution to form consensus on the best solution. Donte provided written feedback, guidance, and praise in the notebook.

Donte reflected that this process closely mirrored his own experience with interning at a large engineering firm. He stated, "[The project] was real world. At my job, we didn't turn in our own individual packet of what we discovered, but we all collaborated on one central form".

Following the research stage, Milania asked each student to sketch a model that could inform the design on the prosthetic hand. Students used their phone or Chromebook to take pictures of sketches and upload them into the engineering design notebook. Donte provided feedback such as "specify the type and brand of materials you will use, " "define your measurements on your sketch", and probed student thinking by posing questions such as "What are the sizes of your rotational joints?" Figure 1 shows an example sketch and written explanation from a student within the engineering design notebook. This student illustrated how motors can be used to create full range of movement for the hand. Milania then asked students to identify physical materials that could represent their sketched designs. On one shared page of the notebook, students synchronously wrote ideas that included:

- I could use the hole of a cup handle to keep the hand in place.
- I could use a pencil to hold the hand up in place.
- I could use a stapler as the grip of the hand.
- I could use a chord to connect my hand to a computer and plug into an outlet.
- I could tape a straw to the hand.
- I could use the handle of a lunchbox to tie the string of the hand to.
- I could use a hand sanitizer bottle to stick the string of the hand into.

While students did not use these materials to construct models, Donte and Milania used this activity to have students consider the structure and function of diverse models and how systems can work together with simple components and innovative ideas.

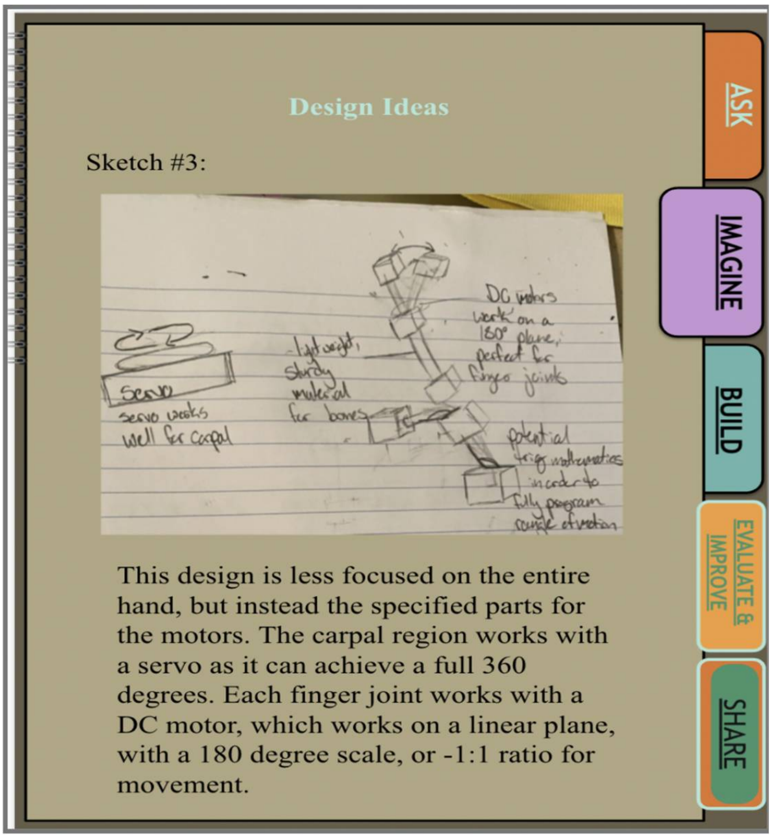

Figure 1. Student's sketch and design idea for mechanical hand.

In the following class, Donte introduced them to AutoCAD, a 3-D design software. The partners provided time for the students to practice with this software. Students used small Zoom breakout rooms and screen-sharing features to design components of the hand. Milania and Donte entered the break out rooms with two-three students to provide personalized guidance. Milania 3-D printed each component of the students' designs. Milania also requested project grant funding to supply each student with an Arduino starter kit and simple materials to program a hand to move from home. Students picked up these kits in boxes that were placed outside of the school. During one class, Donte used the engineering design notebook to organize instructions from the Arduino manual, while he modeled how to use Python to code the motions of the hand. He also inserted instructional videos from YouTube into the engineering design notebook and listed codes that students may need to make their device function. Given the small number of students, Donte and Milania were able to support each student to assemble hardware and code the mechanical hand from home.

In the final class, students presented their mechanical hand over Zoom. Donte also demonstrated the completed 3-D hand that was designed earlier by students through AutoCAD. He demonstrated how this model hand could function in the same way as the simplified models that students designed from home using their Arduino kits. Milania then asked each student to write an open-ended reflection of their experience within the engineering design notebook. One student reflected,

> For a group of students and mentors all learning to adjust and adapt to the new changes in our lives, it is amazing that we were able to come out with a final project. Personally, being able to participate in this project has extended my knowledge of coding further into what I already knew. I previously worked with Java for the robotics team, and now I'm more familiar with the working of Python and AutoCAD. With this project, myself, along with my teammates, were introduced to AutoCAD 3D software and circuitry, being able to build circuit boards and motors all on our own. All in all, this project was a great learning experience for myself and many others. With this opportunity, we have been able to learn and grow, all the while culminating new interests for STEM careers.

This short passage from a student's larger reflection demonstrates the complex processes and concepts learned through this experience. Further, the reflection shows that this student took pride in their collaborations with their peers and mentor to successfully complete a rigorous challenge in the COVID-19 learning environment.

3.2. Elliot and Michelle: Providing a Mirror to See a Future in STEM

At the time of the study, Elliot had been teaching middle school for 16 years as a middle school marine science teacher. During the 2019–2020 academic year, Elliot participated in the project and was excited to be paired with a Black female undergraduate again in a hybrid online context. Specifically, in an interview, Elliot noted that this type of partnership "gives a mirror" to underrepresented females in the class, showing them the possibilities for a future in engineering. Elliot also stated that the STEM undergraduates helped him to see the importance of the "iterative nature of design" and "the "importance of trial and error" in teaching the EDP, which complemented his understanding of marine science. He was paired with Michelle, a fourth-year biological systems engineering major who had extensive informal STEM education experience, both as a learner and a facilitator. Throughout Michelle's formative years, her mother "threw her into a bunch of camps about science and engineering." These experiences fostered Michelle's desire to bridge engineering and education in the future. Michelle shared,

> I hope to use my engineering background and also my experience working with students in making experiences fun for them, especially for underrepresented students who may be turned off about the idea of STEM, because it's too hard, or something like that. So being able to do that is really inspiring for me. And

> eventually I hope to make my own program. I'd like to make a summer camp or something where students can go and have the same experience that I had when I was younger.

After being initially introduced via email, Elliot and Michelle quickly began planning together. They decided to begin their challenge in the spring semester of 2020–2021 when students were given the option to attend school two days a week in a hybrid class experience or continue learning remotely. The partners constructed an engineering design task about a fictional city that faced water insecurity. In a master planning version of their engineering design notebook, Elliot and Michelle detailed the following problem for students to address:

> Water insecurity is an issue that affects people in several countries, including the United States. Water is used for multiple things like cooking, drinking, and taking a shower. On average, each household uses about 100 gallons of water per day. When a community does not have a way to transport water, it becomes difficult to perform those daily tasks. The town of Thornberry is classified as water insecure. With a rising population, they need to find a way to transport water from the nearby river to their community. Your challenge is to design and build a system that would collect enough water to sustain Joseph's community.

Michelle offered to design all the curricular materials for the engineering design notebook. She placed pictures, texts, and videos into the engineering design notebook to develop a relevant context for students. When describing her rationale for taking on this responsibility, she states,

> He [i.e., Elliot] didn't necessarily task me to do this. I kind of just took it upon myself to do that because I plan to go into education which is why I wanted to take up a lot of the project. And also I was trying to find things that relate more to them since I am working with predominantly African American students, and other minority groups.

In three weekly Zoom meetings, Elliot provided feedback to Michelle on her ideas and together they modified learning activities to meet the academic needs of students. Specifically, Elliot explained, "For me it was more about scheduling, like you know how much time does a middle schooler need to do this kind of thing and applying what I know to expect from students on the project, and what they'd be capable of." Elliot identified one of his classes for Michelle to join weekly; students in this class faced overwhelming challenges at home and were often absent. Seven students were consistently present for in-person activities. Elliot made individual copies of Michelle's master notebook in Google Slides and placed them in each student's personal Google Drive folder outside the Canvas LMS. This approach allowed all students to participate in the engineering experience, have personalized feedback, and not be hindered by a peer's absence from school when working on the notebook. Elliot explained, "Based on what I've seen so far, I did not want to have a group where one person is doing all the work and the other person doesn't show up." Elliot shared each student copy with Michelle so that she was able to connect with and provide feedback to each of Elliot's 20 students.

Michelle joined Elliot's students each week over Zoom during this semester. Elliot recalled one of his students seeing Michelle for the first time. He said, "I'm just going to be honest, [student name] is a young Black girl and when she saw Michelle, she perked right up and her attention peaked. That shows the value of this whole thing." Michelle personalized an engineering design notebook for students that included pictures, Bitmoji's, and information about herself. In the first week of the project's implementation, she introduced herself to students synchronously online, talked through her introductory page in the engineering design notebook, and got to know the students by allowing them to ask her questions. Many students used the chat feature in Zoom to ask about her major and interests. Within the engineering design notebook, students introduced themselves through pictures and written descriptions. Michelle wrote personal comments back to each student using the comment feature in Google Slides, asking them questions about their hobbies and interests. Michelle maintained this practice through every stage of the EDP. Figure 2 provides an example of personalized feedback Michelle gave a student when they were defining the engineering problem. Michelle explained that she enjoyed giving the online feedback and explained, "When [the students] go home and then come back and they see 'oh there's a new comment here, like somebody actually looked at it', I think that gets them going".

In each class, the partners focused lessons on each stage of the EDP. Elliot began each class with directions for approaching the learning task. Michelle monitored students online while Elliot was speaking. During one class, Michelle noticed that students online were having difficulty describing what the engineering problem was. She described that experience and her observations,

> So we asked them some questions to make sure they understood what they were supposed to be doing [i.e., writing a problem statement]. I don't know if I just didn't phrase [the question] correctly because I thought it would be very simple to use text and relate it back to a picture because you have to do that on standardized tests. I assumed they knew how to do it, but some students weren't understanding, and then some students were. I did notice that the Caucasian students were understanding this more than African American students were. There were a few that did understand but some of them didn't at all. Out of the whole class of like 20 something [students] only probably five students got this right. And, like, three of those five were Caucasian students.

While Michelle did not share that she noticed this with Elliot, during an interview, she reflected on why so few students seemed to understand the directions. She pondered, "Because they're sixth grade students, they all come from different elementary schools and their educational backgrounds are different." She continued, "you don't know what the home environment is in terms of [educational] support. I have to sometimes remind myself that these kids are sitting at home doing this." Michelle quickly adapted to the role of clarifying directions to students who were learning remotely, meeting with them in small breakout rooms to support their work. Michelle used virtual models, web links, and pedagogical literacy strategies in the engineering notebook to scaffold students' research on the role of water in third world countries and ways to address water insecurities. While Michelle shared new ideas and discussed research with students, Elliot held them accountable and kept them on pace in the engineering design notebook. Specifically, he used GoGuardian® to monitor students' progress on school laptops and would chat with students in person and online who were off-track.

Elliot created and disseminated small kits of inexpensive household materials for both in-person and remote students. These materials included plastic cups, popsicle sticks, bamboo sticks, plastic plates, electrical tape, duct tape, rubber bands, paper fasteners, zip ties, a 5-gallon bucket, and a small metal bucket. Given students' diverse needs and abilities, Elliot and Michelle explicitly told students that this assignment was not a competition. Elliot and Michelle also taught students how to use Flipgrid, a video presentation and discussion tool. This technology supported students in creating two-minute video clips to share information about their process and reflect on their work. Michelle provided a prompt for reflection that asked students to describe (a) how their solutions related directly to the problem of water insecurity, (b) the similarities between their solution and what other scientists and engineers have done, and (c) how the challenge helped them to understand the processes of engineering. In-person students presented their approach to the challenge aloud with their peers; eight students who were learning remotely embedded Flipgrid videos in their engineering design notebook. The Flipgrid videos creatively illustrated how students thought about their EDP to address the challenge; some students held up their cell phones in Flipgrid recordings or showed paper drawings that illustrated their prototypes and ideas. One sixth-grade remote student reflected on her proposed solution through a Flipgrid video; she stated,

> [My solution] is similar to others that scientists and engineers have found because [they found that] there are holes at the sides of urbanized land that open out to flowing bodies of water like my design. However, my design has the hole underwater so that the water can come to the town. So [it's] somewhat like an underground pipe system.

This reflection exemplifies how students were able to use Flipgrid to communicate their thinking and present a solution to their peers, teacher, and undergraduate mentor. At the end of the project, Elliot conducted an informal survey with his students on whether they would consider engineering as a career. He shared that six of his students reported a greater interest in the field due to their experience in class.

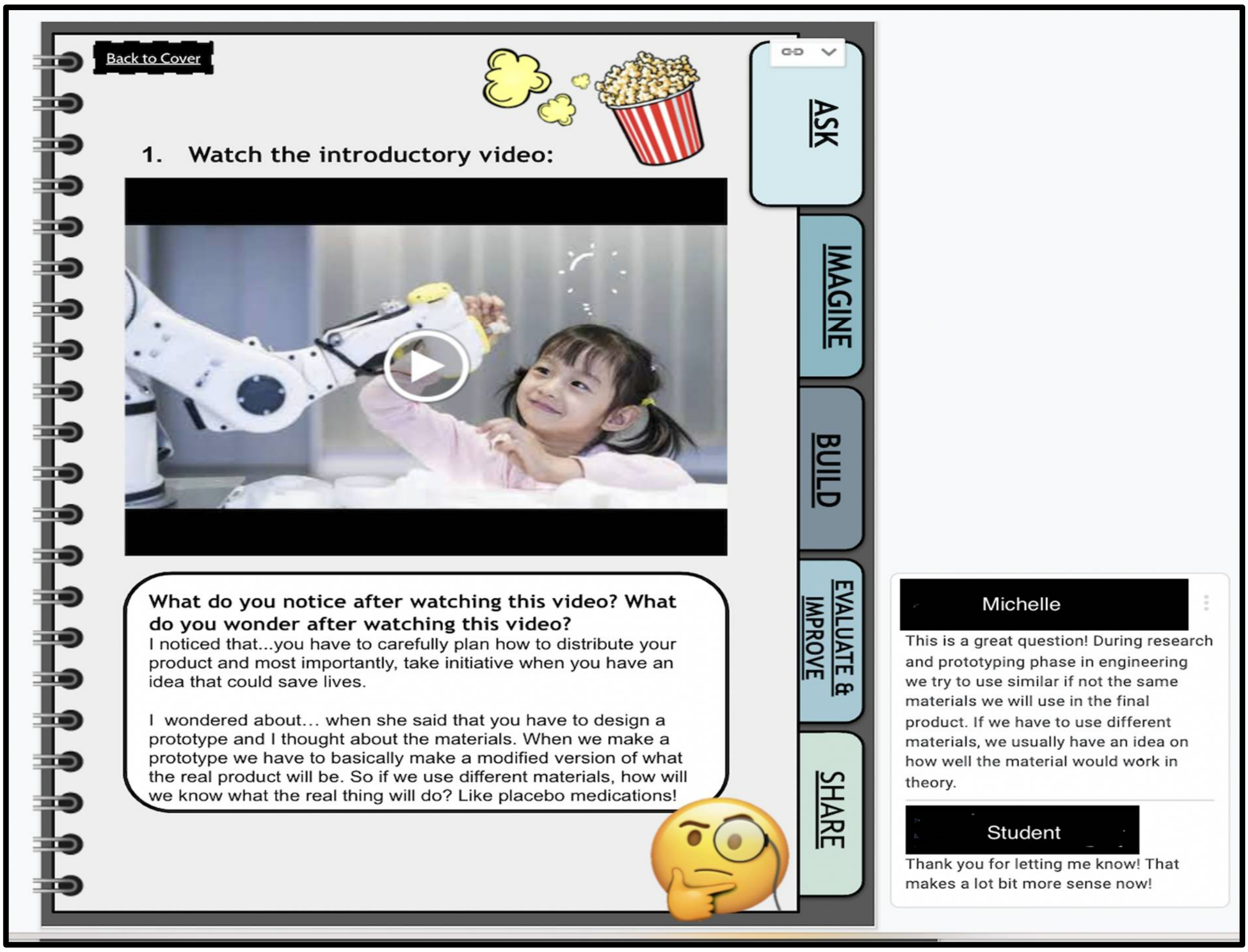

Figure 2. Example of student work in the engineering design notebook and the undergraduate's feedback.

When reflecting on the collaboration, Michelle praised Elliot's support of her role in the project. She explained that neither partner had "a pride complex." She elaborated on this by sharing the following statement:

> I wasn't too prideful thinking like 'oh I'm an engineer [and] I'm better than a teacher.' He wasn't like, 'oh, I've been teaching for so many years and we're not going to do this so I really appreciated the openness and the collaboration. I felt very respected in the classroom.

Michelle's remark underscores the importance of partners' dispositions when engaging in collaborative work. Elliot and Michelle communicated openly, developed a level of trust with each other, and centered planning and instruction on the needs of students.

3.3. Willow and Brielle: Promoting Student Voice through Music and Justice

Willow formerly worked as an instructional technology specialist in industry and educational organizations for twenty years prior to becoming a middle school technology teacher. Willow committed to the partnership and project in her first year of teaching during the global pandemic. She taught technology and computer science classes to sixth-, seventh-, and eighth-grade students. In an interview, Willow stated that she wanted to engage in the project to show students that "engineering is for everyone, not just the smart kids, or the ones who like math and science, or even the ones who want to be an engineer engineering is a part of every job, every career, [and] everyday life." She stated that "engineering needs to be relevant" and that "you have to bring it to them, [understand] how they see it, not just the term [engineering], but bring it into their culture and [show] how it applies to them." Willow was paired with Brielle, an undergraduate computer science major in her third year. Brielle developed an interest in engineering in middle school when she joined a school club "for minorities in engineering." By her senior year, Brielle became president of this organization and participated in and facilitated engineering activities and competitions across the region. Her parents often told her that she was "gifted in mathematics and science" and encouraged her to apply to a gifted program in high school. These experiences contributed to her passion for engineering and this collaboration.

When Willow met Brielle in the fall semester of 2020, Willow suggested that they adapt the engineering design notebook to implement a large coding project in the spring semester with sixth-grade students. Willow explained to Brielle that waiting until later in the academic year would give them time to understand her students' abilities and needs. From October to March, Willow welcomed Brielle into her classroom virtually at any time and gave her access to a recurring Zoom link. Brielle visited Willow's virtual classrooms 3–4 times a week, getting to know students in all of Willow's classes. Willow stated that Brielle "had really good feedback and was super present in her classes." She became a regular addition to the classroom and a knowledgeable mentor, virtually building relationships with students. Brielle even served as a volunteer engineer representative for an afterschool club that Willow led, called *Girls Code*. Because of this, Brielle understood Willow's curricular sequence and instructional methods. Brielle stated that through this process, she discovered "how the students best learn and stay engaged".

Willow introduced Brielle to an established online coding project called *Your Voice is Power* and shared that she wanted to adapt the established online modules to serve as the collaborative engineering design challenge using the engineering design notebook [52]. This project was created through a partnership between Amazon and singer Pharrell Williams. The purpose of the project was two-fold. First, it taught students how to use the coding language (Python) to create a song in Earsketch, a virtual workspace that imported code to produce music. Second, the project showed students how entrepreneurship can be used to combat racial inequality. While Willow would implement this project with all her students, the partners identified one sixth-grade class that Brielle could consistently attend and provide ongoing support to students. Willow and Brielle met weekly through Zoom, and even once in person to adapt the *Your Voice is Power* project to the engineering design notebook. Together, they scaffolded the content provided in the online modules to follow the EPD, and situate it within the engineering design notebook. Brielle included Bitmojis, pictures, and texts about herself to personalize the engineering notebook and held a synchronous online question and answer session with students prior to the launch of the project to answer students' questions about herself and her field of study. She recalled during her exit interview, "I told them my major, cool things that I have seen in my field, which is AI, drones, and making video games. I tried to make it a little bit interesting and relatable for the students so that they felt comfortable asking me questions or coming to me if they needed help".

Before the project began, Willow decided to remove the engineering design notebook from Google Slides and separate the stages of the EDP into the Canvas LMS. Willow provided more context to this approach in an interview. She stated,

> [The design notebook] is going well. I had to make adjustments for the class I'm doing with sixth graders. And they are doing much better because I have broken it up into chunks. So I think by design, the notebook has the hyperlinks for the tabs. Instead of doing that, I took the notebook and I broke it up into the five parts [i.e., stages of the engineering design process]. So they do the first part, the ask [stage], but for them, it says "intro" because it's their intro to ear sketch. They just do those slides. They don't see the other pages until they have completed those pages. That worked really well, because it was just too... I think it would have been too overwhelming to have everything all at once, even though they can click and go to each section. For middle schoolers. I think that that would have just been a little bit too much. So I just broke it up.

While Willow's decision to organize the EDP on the Canvas LMS met the needs of Willow's students, it presented an obstacle to Brielle for writing feedback comments in the engineering design notebook. Due to the security settings of the Canvas LMS, it was difficult for Brielle to see students work. Willow explained, "I had to think of an alternative that could be outside of our learning management system so that she could communicate with them back and forth...so that's why I added the Flipgrid." Because Brielle was virtually present in all of Willow's classrooms, she was able to overcome the challenge of not seeing the individual notebooks of the students, and communicate with them through Flipgrid. Both partners felt that Flipgrid was a powerful tool for students to convey their research, designs, challenges, and reflections to their teacher and undergraduate mentor. Willow stated, " I honestly think that students will communicate more just by speaking than if you tell them to go into a document and type. Additionally, she noted "I think because we're in a virtual environment [Flipgrid] helps them to also connect with whoever it is that they're talking to." Brielle echoed this sentiment and noted that the decision to use Flipgrid as a means of communication and for feedback actually helped her to feel more connected to Willow's students. She stated,

> Usually on Zoom, they don't really have their cameras on. And so you just see like a bunch of black screens. But Flipgrid is really cool, because you get to see your students, see who you're talking to, and actually be able to communicate with them.

Willow and Brielle drew upon the *Your Voice is Power* resources to guide Zoom discussions about racial injustice in society with students. They tasked students to use their power as songwriters to stand up against inequality. Willow and Brielle worked in small groups with students, in-person and synchronously online, to dissect the problem. They guided students through music videos and video accounts of children who reflected on privilege and injustices. Both Willow and Brielle held students accountable to write definitions and reflections on racism, privilege, stereotypes, and prejudices within the notebook, carefully scaffolding interdisciplinary literacies through the process. Students were asked to analyze Pharrell's music lyrics from the song *Entrepreneur* [52]. Pharrell's song lyrics discussed the incarceration of young Black men and systemic racism. Then, students were asked to analyze the layers of tracks within the same song. Using Earsketch, the students then created their own songs through coding. Figure 3 shows Willow and Brielle's introduction to designing songs (i.e., the building and revising stages of the EDP).

While students did not have an opportunity to reflect on the totality of their learning experience in the design notebook, Brielle shared her perspectives on collaboration, digital tools, and learning outcomes. She stated:

> I felt really connected to my students and my teacher, throughout this process, I think what helped with that was definitely the Zoom meetings, meeting on a regular basis, and being able to use Flipgrid to communicate to the students. It was an eye-opening experience for me. It taught me how students learn and how they respond to different activities. I'm used to being a student, but for once, I got to see the teacher's perspective, what goes on behind the scenes, what goes

> into making a lesson plan, and making activities for the students so that they're engaged. So that was very interesting for me to learn.

For Willow and Brielle, the collaboration, digital tools, and project implementation were guided by iterative feedback from the students. This approach allowed them to modify activities for the students and reflect on changes that should be made to the project post-pandemic.

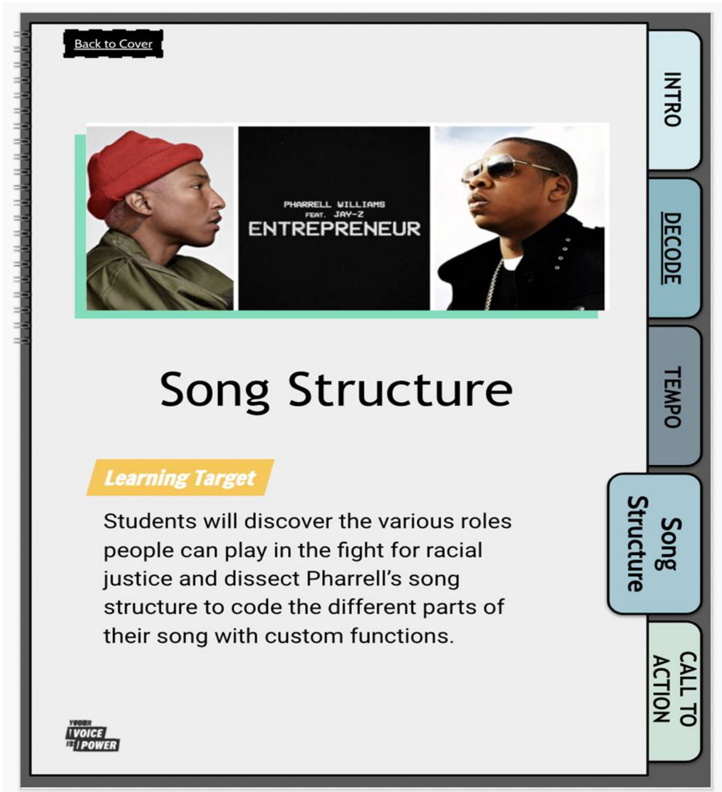

Figure 3. Example section of Willow and Brielle's engineering design notebook.

4. Discussion

Our case studies explore how secondary STEM teachers leveraged partnerships with undergraduate mentors used digital technologies and promoted equitable learning experiences for students in the context of emergency remote learning due to COVID-19. Table 2 provides an overview of our cross-case analysis that describes how each teacher/mentor dyad used various technological tools and pedagogical structures to support students' content knowledge and skills, foster social connections, and promote culturally relevant learning opportunities for secondary students. In this section, we discuss how these decisions led to culturally relevant learning opportunities for students, specifically the ways in which teachers promoted high academic standards and rigor for students, supporting their cultural competence, and promoting socio-political competence and connections to STEM [15].

Table 2. Overview of cross-case analysis.

Cases	Milania and Donte	Elliot and Michelle	Willow and Brielle
Context of facilitation	Completely virtual	Some students in class/some online	Some students in class/some online
Design task	Mechanical arm	Water transport device	Coding music to combat racial injustice
Technology	One engineering design notebook for the class; Zoom; Python software; AutoCAD; 3-D printer; Arduino starter kits; Canvas LMS	One engineering design notebook/student; Zoom; Go Guardian; Flipgrid	Adapted sections of the engineering design notebook; Earsketch; YouTube; Python; Zoom; Flipgrid; Canvas LMS
Pedagogy	Direct instruction; Discussion; Small groups; Peer–peer feedback; Mentor–peer feedback; Modeling; Differentiation; Reflection	Direct instruction; Discussion; Small groups; Mentor provided feedback to students; Pedagogical literacy strategies; Student presentations; Accountability structures; Reflections	Whole-group instruction; Small group discussions; Modeling processes phenomenon; Personalized discussion between teacher, mentor, and individual students; Pedagogical literacy tools
Content	Anatomy/ Physiology of a hand; Current developments in medical technologies; Programming language; Circuits; Engineering design practices	Water insecurity; Water filtration; Water pumping and lifting devices; Engineering design practices	Python code language; Earsketch functionalities; Music analysis; Entrepreneurship; Racism; Privilege; Stereotypes; Engineering design practices

4.1. Promoting Academic Excellence and Equity

Culturally relevant teachers ensure that all students have access to learning opportunities to succeed in their classroom [15]. In the context of COVID-19, access takes on a multitude of meanings including access to necessary technologies, learning materials, and academic, emotional, and social support. The three teachers in this study adapted content, pedagogy, and technology to provide opportunities for remote and hybrid students. Teachers ensured that all students received software such as Arduinos, AutoCAD, Python, and Earsketch and physical materials to engage in the design processes, and even delivered materials to students' homes. When undergraduates put forth creative and interdisciplinary applications of engineering, teachers scaffolded the ideas so that their students could access learning opportunities in an organized and coherent format. The teachers' knowledge of their students was critical in this context of remote learning as undergraduates did not have formal teaching experience, nor saw the students on a daily basis.

The teachers and undergraduate mentors piloted pedagogical practices in the moment to ensure that students could collaborate and communicate through Zoom, the engineering design notebook, and Flipgrid. Each of the teachers worked with students who had different academic, social and emotional needs that shaped the ways that the teacher and undergraduate navigated the partnership and led the project. Milania and Donte worked with a small group of academically advanced high school students, and were able to give the students more autonomy in their learning. Further, the context presented a situation where all students could collaborate together with Donte and Milania on the same challenge, and receive individual support when needed. In the other cases, the teacher and undergraduate had to take on more distinct roles to differentiate content when some students were learning from home and others were learning in person. For example, Michelle was able to identify that the students who were learning remotely, specifically minority students, needed additional accommodations and support from her. Willow realized that her sixth-grade students needed to have the stages of the EDP removed from the engineering design notebook and presented them in a less overwhelming way through the Canvas LMS. Brielle and Willow used a gradual release of responsibility approach [53], where they modeled how to use hardware and software, provided students with opportunities to practice with their peers while receiving feedback, and then gave students time to individually apply and reflect upon these tools. Teachers' differentiation and alignment of content, pedagogy, and assessment through the use of digital technologies is essential to promoting positive outcomes for diverse learners [9,54].

4.2. Promoting Students' Cultural Competence

When teachers support students' cultural competence, they are "helping students to recognize and honor their own cultural beliefs and practices while acquiring access to the wider culture" [55] (p. 36). As described earlier in the manuscript, the culture and practices of STEM are largely dominated by heteronormative white discourses and ways of knowing [19]. The teachers recognized the value that undergraduate mentors of color brought to their classrooms. For example, Elliot demonstrated this when he said that Michelle provided a "mirror" for his African American females, and Willow stated the importance of all students being able to see themselves as engineers. The scheduling, logistics, and digital technologies used to facilitate the partnership did not come without challenges. However, all of the teachers believed that minority representation in STEM classrooms and fields matters. In situating the undergraduates prominently as knowledgeable others in the classroom, the teachers countered the narrative that only white individuals can be successful in STEM. This supports findings from the authors' earlier work describing how teachers and undergraduates collaborated to promote culturally relevant education in person [45].Teachers' efforts to learn the technologies, find time to schedule Zoom meetings and plan with undergraduates, navigate obstacles for the undergraduates to work with students, and share their students' work with the district and research team speaks to their dispositions towards social justice and why they are recognized as STEM leaders.

The undergraduates provided multiple opportunities for students to express who they were through the engineering design notebook, Zoom, and Flipgrid. Through students' interactions with their STEM undergraduate mentor, the students' experiences and interests were acknowledged and valued while also learning about their mentors' STEM field experiences in college. Undergraduates affirmed students' contributions through written and verbal feedback. They also supported students' cultural and navigational capital in the field of engineering as they modeled how engineering is practiced in the real world, through trial and error, collaboration, questioning, and ongoing feedback cycles [56]. The teachers were open-minded and flexible in the planning and teaching with an undergraduate, providing undergraduates with autonomy to form an authentic presence in the classroom. These attributes align with successful collaborative practices between teachers and undergraduates in the prior study by the authors [45]. All of the teachers positioned themselves in ways to support students in their pacing, organization, and accountability, which further promoted relationships to be built between undergraduates and students. The virtual collaboration between teachers and mentors provided students with a secondary teacher in the classroom and a "near-peer" who built upon and supported students' social and intellectual capital [13]. Because the undergraduate mentors also had a deep understanding of the content matter, they were able to co-facilitate classroom sessions by working in small groups with students and providing feedback. In this way, the undergraduate mentors functioned as supportive resources who co-teachers which helped facilitate learning during hybrid sessions, addressing the individual needs of students to assess their individual understandings of content and processes.

In all of the cases, students were able to authentically show their learning by creating a product (e.g., a robotic hand, a water transport system, and a song). Many students expressed a desire to participate in future STEM opportunities because of their work with undergraduates, supporting the importance of mentorship in STEM [40,41].

The learning activities within the notebook showed that teachers and undergraduates valued the cultural ways of knowing and language that students brought to the task. This was primarily evidenced through the modes of reflection that the pairs incorporated into their projects and the writing to learn activities when students could document their understanding. Students were asked to generate their own questions, research areas of interest, actively reflect upon how their lived experiences contributed to their understanding, and in the case of Willow and Brielle, provide constructive feedback on learning activities. When teachers provide opportunities for students to insert their voice into learning processes and take ownership of their work, they are supporting students to maintain their cultural integrity while reaching for high academic standards [15]. Research indicates that opportunities for students to reflect on their learning promote self-regulation skills, sense-making, and connection to curriculum [15,57,58]. The ways in which teachers and undergraduates used reflection in assessing learning shows the possibilities for assessing STEM beyond standardized tests and recollection of facts [57].

4.3. Promoting Socio-Political Consciousness

All of the cases applied engineering in ways that highlighted empathy, justice, and agency. Their actions exemplified connected learning where academics were intricately tied to career opportunities and civic responsibilities [3]. These real-world connections promoted students' socio-political consciousness in STEM classes as they provided students with opportunities to apply science and technology concepts to solve engineering problems through a social-justice lens [55,59]. Undergraduates drew clear connections between middle and high school science and technology topics to the needs and constraints of underserved communities and marginalized people. Connections between STEM and issues of social justice have been found to make science and engineering more engaging for students of color [60]. Specifically, we found that Donte and Milania had students design a hand for a relative. Their emphasis on empathy in the EDP has been supported as an important practice for students to develop in engineering coursework at the higher education level [61] and important during the COVID-19 pandemic to bring students together around the needs of people [62]. Similar to Donte and Milania, Elliot and Michelle also encouraged students to empathize with families who faced water shortages and consider how this would affect their daily lives and futures of their children. Water insecurity is one of the most significant issues facing the world's population, especially in developing countries and can be attributed to a variety of factors, including social exclusion and environmental racism [63]. Elliot and Michelle supported students to develop socio-political consciousness and agency as they created water filtration devices to help a community in need.

Willow and Brielle's engineering design project directly focused on social justice, issues of power, and providing students with a voice through curriculum and learning activities to take a stand against inequality through music and entrepreneurship. This project was particularly powerful given the polarized social relationships and racism that is deeply sewn into the fabric of the United States and broadcasted daily in the media. Willow and Brielle's approach to engineering helped students think deeply about science and technology concepts and processes while building on their funds of knowledge and cultural resources to reflect upon race and racism and have a voice through discussions and creation of music. The curricular resources drew on students' interests in music, specifically hip hop. Hip hop pedagogies can support students' understanding of science content and encourage their voice and agency [64]. In centering Black voices and hip-hop culture, Willow and Brielle's project helped foster cultural pluralism and worked against creating a monocultural society [65].

5. Conclusions and Implications

The three cases presented in this study illustrate the intentional decisions that teachers made in selecting content, pedagogy, and technology, and connecting students to learning through culturally relevant educational experiences that built on their backgrounds and culture, promoted their academic achievement, and critiqued broader societal issues. The context of the partnerships and the findings presented in this study offer key take-aways for those seeking to design partnerships between teachers and community members using digital tools. First, the authors had a well-established and trusting relationship with the school district partners. The district had been a key partner in our teacher education program, regularly collaborated with our School of Education in professional development, and shared core values with us on equitably serving students. Further, district administrators and teachers had the opportunity prior to the pandemic to pilot collaborations with undergraduates and saw first-hand the power of these partnerships for students. We relied on the STEM professional development coordinator to share the successes of prior teacher–undergraduate collaborations with new STEM teacher leaders. The STEM professional development coordinator deeply understood the needs of the teachers with whom she worked. She coordinated monthly meetings with the researchers, teachers, and undergraduates, helped distribute physical materials to schools and reviewed teachers' engineering design notebooks in one-on-one settings. Thus, administrative buy-in was and is essential to similar implementation-research projects with teachers.

Second, the teachers and undergraduates were committed to the overarching goal of the project and wanted students to have experiences that were not typical in STEM classes during COVID-19. The teachers were classified as leaders by their administrators and had a disposition to test out new ideas in their classrooms and adapt according to the needs of their students. The leadership abilities of the teachers were complemented by the community partners, the undergraduate mentors, who clearly understood that their role was to support the teacher with engineering activities for students who were learning from home. We met synchronously online with undergraduates prior to their collaboration with teachers to discuss the context of middle and high school science classes, how engineering is defined at the K–12 level, how an engineering design notebook might be implemented, and how they could provide quality feedback to students on at the different stages of the EDP. We recommend that community partners and teachers participate in discussions with those designing the structure of implementation ahead of time to consider logistical questions and to generate ideas together. Organizations like the NSBE are well positioned to partner with educators because they often have regular experience with K–12 student outreach.

Third, the teachers who completed the project (i.e., four of eight teachers) with an undergraduate during COVID-19 were not bound to a scripted curriculum that was tied to a standardized state test. We feel that teachers who taught these tightly-paced courses would have needed more structured planning time with their undergraduate and the research team. Unfortunately, this was not possible during a time when teachers had far more responsibilities than normal and were piloting new online curriculum and assessment procedures. Several of our participants also had small children at home so they had to navigate teaching online, while also supervising their own children's' virtual learning at home at the same time. Our work with teachers and undergraduates pre-pandemic did show great promise for teaching science and mathematics standards through engineering challenges [45]. To address the issues of time constraints, we encouraged dyads to communicate early and often and asked them to identify and share their preferred mode of communication with each other. We encouraged dyads to keep open lines of communication and many found that texting on their phones was the most efficient way to communicate issues that arose as they planned for instruction. The university researchers also hosted monthly meetings which all dyads and district coordinators attended. During these meetings, mentors and teachers brainstormed together and shared positive examples of learning activities from the year prior. These factors helped contribute to a community of practice [43] where mentors, teachers, university researchers, and district administrators could share ideas and resources with one another. In addition, every two weeks, we sent a check in form (via google forms) where we asked teachers and mentors to reflect on their work in the last two weeks, identify plans and goals for the next two weeks, and document any concerns or areas where they needed additional support. These forms served as an important data point and accountability measure as it helped us and the district administrator identify who could use additional assistance.

Finally, these cases provide implications for the use of digital technologies to promote collaboration among students and also between partners who are not part of the school district. The teachers leveraged tools that were familiar to students and that created organizational structure for students to learn from home. For example, they relied on learning management platforms, communication tools, and accountability mechanisms familiar to learners so that a priority could be placed on learning the engineering design process and collaborating with undergraduates. While the partners saw advantages to the engineering design notebook, they were flexible in its implementation. The teachers creatively navigated technological challenges such as troubleshooting the necessary permissions of the LMS, Google Slides, and Flipgrid to allow the undergraduate mentors to directly work with their students. Teachers, then, felt a sense of agency in adapting the engineering design notebook to their students' specific needs and contexts, while also adding in other technology tools to achieve the ultimate learning goal of having their students collaborate on an engineering design solution with their mentors. As teachers continue to be asked to implement new digital tools into their classrooms post-pandemic, we suggest that implementation researchers and administrators engage in conversations with teachers to unpack how new technologies can be adapted to support students' specific learning needs and outcomes.

In conclusion, as we reflect on the lessons learned from teachers and students during the COVID-19 pandemic, these cases help us to reimagine what learning could look like moving forward. The teachers featured in this study showed creativity as they leveraged digital tools and virtual collaborations with STEM undergraduate mentors to promote equitable STEM learning experiences for students. We found that the virtual learning environment provided a unique context for teachers to connect learning to social issues with the support of an undergraduate STEM major. In a practical sense, the undergraduates shared the responsibility for students' learning, which was helpful for connecting learners to social and academic practices. Together, the teachers and undergraduate mentors demonstrated exciting possibilities for connecting STEM learning with social issues and building solutions as a community. The technology tools selected by the teachers provided affordances that allowed the undergraduate mentors to give feedback to students both synchronously, for example, through small break-out rooms in Zoom, and asynchronously through the comment function in Google Slides and Flipgrid videos. In concert with the teachers' and undergraduate mentors' pedagogical decisions and content knowledge, these digital tools provided opportunities for students to collaborate and experience social connections and culturally relevant educational experiences despite being physically distanced from their peers, teachers, and mentors. We see opportunities to continue to enrich and expand these virtually mentoring experiences not only within the United States but also internationally.

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dance with the Department of Health and Human Services Federal Regulations: 45CFR46.104.d.1, 45CFR46.104.d.2. This states that studies are exempt from formal review when: 1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods, and 2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if any disclosure of the subjects' responses outside of the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation.

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