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My Code Isn’t Working! Mathematics Teachers’ Adaptive Behaviors During an Engineering Design Challenge (Fundamental)

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My code isn't working! Mathematics teachers' adaptive behaviors during an engineering design challenge (Fundamental)

Trying something outside of the typical teaching strategies that teachers employ can be daunting and challenging. This paper addresses issues of adaptive expertise in the context of high school mathematics teachers integrating both engineering and microelectronics in the classroom. The push to integrate microelectronics in pre-college education spaces has come about due to the rising desire and focus of bringing microchip manufacturing back to the United States. As part of the CHIPS Act, the U.S. federal government set aside a significant amount of money for research on developing trusted and assured microelectronics, as well as providing an infrastructure for major microelectronics workforce development projects [1]. This was driven by a shortage in microchip manufacturing ability within the U.S. and the desire to build the capacity for chip development and manufacturing across the country. Due to this growing pressure to integrate microelectronics content and contexts in the classroom, teachers are now being asked to help students become familiar with microelectronics and learn more about potential career paths in the field. In order for teachers to successfully implement a robust microelectronics integration that also addresses the core standards and learning objectives required in their courses, they will likely be expected to utilize technological tools with which they may be unfamiliar.

Teachers are often expected to introduce novel content in their classroom that may not be familiar to them. Researchers explored this phenomenon in practice when states shifted to the Next Generation Science Standards (NGSS) and the presence of science, engineering, and technology altered the expectations for student learning [2]. Technological literacy was not expected of veteran mathematics teachers but is more common in current teacher education programs [3]. The in-service teachers' beliefs about the purpose and role of instruction impact the ways in which they may adopt curricular content and technological tools in their classroom. Thurm and Barzel [4] explored the complex relationship between mathematics teachers' beliefs and technology use. One of their findings highlighted teacher self-efficacy in implementing technology when more integrated, constructivist methods were present. Not unsurprisingly, technology in the classroom tends to be more difficult for teachers with more of "a procedural focus than an explorative one" (pp. 57) [4]. Mathematics instructional material traditionally includes one right answer which does not align with more explorative pedagogy. Yet in order to integrate microelectronics in a way that inclusively introduces the field of microelectronics, provides information about workforce pathways, and teaches the core mathematics concepts requires that teachers have a constructivist mindset paired with flexibility and adaptability [5].

Research highlights both challenges and benefits in fostering connections between STEM subjects, particularly engineering and mathematics. While integrating these disciplines can improve student engagement and problem-solving skills [6-7], challenges include siloed curriculum structures and teacher training focused on specific subjects [8-9]. Furthermore, effectively linking engineering design processes with mathematical modeling remains an ongoing area of exploration, requiring innovative pedagogical approaches [10]. However, studies suggest that overcoming these hurdles can lead to a deeper understanding of how scientific concepts are applied in engineering practices, ultimately preparing students for a future workforce demanding a holistic grasp of STEM fields [10].

Due to the push for increased microelectronics workforce development and education efforts, teachers are encouraged to integrate microelectronics-related topics in their classroom. These teachers may have no previous experience incorporating STEM subject matter, specifically microelectronics, in their classrooms. To better understand how teachers without a background in electronics adapt contexts outside of their typical content area to their classrooms, we are asking the following research questions:

> RQ1: How and why do high school mathematics teachers adapt when experiencing technological issues during an integrated microelectronics, engineering, and mathematics curriculum unit?
>
> RQ2: How do these adaptations help students reengage in the curriculum?

Literature Review

This section begins with an overview of perspectives on student engagement in the classroom and connects subthemes of adaptive expertise to adaptive performance.

Student Engagement

To be able to learn, students must be engaged in the classroom. In practice, this looks like teacher observation of student engagement and as a result, adjustment of elements of their teaching on the spot. Engagement in the classroom can be difficult to study because of the wide variability in how engagement is defined, how types of engagement are distinguished, and how these constructs are measured. While behavioral, emotional/affective, and cognitive engagement constitute the heart of engagement [11] researchers have expanded these categories to include social-behavioral, volitional, and agentic engagement [11–12]. Past research on student engagement in science and engineering classrooms centers around core scientific principles like engagement through argumentation with evidence or working in groups while planning and testing designs [12].

Indicators of student engagement may look different in traditional mathematics classrooms compared to mathematics classrooms that are pedagogically modelled using engineering design frameworks. For example, Sinatra and colleagues explain how certain scientific topics may carry different emotional connections with students, thus impacting their classroom engagement [12]. These are referred to as "topic emotions," and for this study, we consider the topic emotions around the contexts in which the mathematics content is embedded. This includes stress and coping, microelectronics, and coding. Any of these topics could impact student engagement. Because the curriculum was codeveloped with the teachers who implemented the unit, their professional perspective about their students' engagement informed the instructional context in which they delivered the mathematics content.

Up to this point, the focused has been on student engagement; however, what we are truly interested in are points of student disengagement. When observing students in a naturalistic setting, "negative deactivating emotions such as boredom and hopelessness are associated with disengagement" (pp. 6) [12]. Previous researchers studying engagement emphasize the importance of clearly defining the "value added" from studying engagement (or disengagement) to not overlap with other cognitive or motivation-related factors [11]. While these other factors are important for holistically understanding students in the classroom, they are outside the scope of this study. Thus, we are focused on the relationship between student disengagement and teacher actions.

To narrow the wide range of engagement related measures, we will focus on behavioral engagement including the social-behavioral dimension [11] as well as agentic engagement [12]. First, social-behavioral engagement aligns closely with engineering education pedagogy where group work is prioritized and students are expected to interact with each other outside of the whole-classroom environment to deconstruct and solve the problem with which they are presented. One way researchers operationalize social-behavioral engagement in science classrooms is by focusing on their social interactions in different classroom contexts [13]. To do this, the researchers linked the individuals' factors of engagement to the classroom's factors of engagement to capture a holistic picture of classroom engagement [13]. Second, agentic engagement is when students actively contribute to the class, driving or altering the instruction, which is a straightforward observable measure in a naturalistic setting [12]. On a macrolevel, we are interested in moments of whole classroom disengagement by observing social-behavioral and agentic actions. However, these moments merely inform the focal point of this study—looking at how teachers *alter* the curriculum in moments of disengagement.

Adaptive Expertise

To understand how mathematics teachers adapt to technological issues in the classroom, we need to explore what makes a teacher an expert. Expertise has been clearly defined in two categories: adaptive expertise and routine expertise [14]. Adaptive expertise goes beyond routine performance of a task and includes the ability to transfer skills, understand solutions, and solve problems [15]. A framework of adaptive expertise in science education can be used to identify three main components that make up an adaptive expert: flexibility, deeper understanding, and deliberate practice [16]. Other definitions of adaptive expertise align with this framework as well, expanding "deeper understanding" as encompassing both conceptual and procedural knowledge [15]. Cognitively, skilled learners will organize information into hierarchical structures as they progress from novice to expert in a given domain [17]. "Adaptive performance" is another trait that is often used to describe the behaviors enacted by adaptive experts. To develop conceptual clarity, one group of researchers explored literature on adaptive expertise and adaptive performance to clarify and distinguish these constructs [18]. The authors found that "having adaptive expertise was conditional on being able to perform adaptively" (pp. 1253) [18]. Additionally, it seems that both adaptive expertise and adaptive performance occur in the presence of a change [18]. Whether this is a changing environment or, in the case of this research study, a change in the type of mathematics curriculum, adaptive performance can be a useful measure of the behaviors observed in experts due to this change.

Teachers' expertise goes beyond content delivery by also needing to navigate the complexities of managing different classroom experiences for all of their students—in other words, exhibiting adaptive expertise. This skillset allows teachers to adjust their instruction and respond to unexpected situations during their teaching. As previously mentioned, three indicators of adaptive expertise in teaching include: flexibility, deep-level understanding, and deliberate practice [16]. Flexibility in teaching shows adaptive expertise in that teachers are not beholden to their lesson plans exactly as written; they are responsive to the needs of students during the learning experience [19]. These teachers show a willingness to experiment, play, change direction, problem solve, and refine based on their own reflection and feedback from students (explicit and implicit).

Suh and colleagues identify patterns which indicate development of adaptive expertise for teachers [20]. They found that an understanding of epistemological tools and a focus on knowledge generation led to adaptive expertise [20]. In practice this can look like a focus on student agency and flexibility in decision-making [20]. A deeper level of understanding for teachers means going beyond their typical domain or content area. This is relevant in this study where mathematics teachers have to teach their content area while integrating elements of microelectronics in an authentic engineering design context. Understanding how new topics can be integrated within a given domain and expanded to include points of connection outside of a domain, are elements possessed by a teacher with adaptive expertise [20]. This component of teacher adaptive expertise has been found to positively impact student learning outcomes in a science domain [16]. Berliner notes the challenge in differentiating between the role of talent compared with deliberate practice when researching teacher expertise [19]. It is important to note that although the teachers in this study have had years of deliberate practice in teaching mathematics, they were not given the opportunity for deliberate practice in teaching engineering pedagogy and microelectronics-related contexts. Therefore, the mathematics teachers who implemented the integrated curriculum can be considered adaptive experts solely in their domain. There is clearly a mismatch between the pedagogical practices needed to teach design versus those used in mathematics and science courses. This qualitative study expands upon this literature and contributes to better understanding teachers' adaptive expertise in a changing classroom.

Methods

Through analysis of two mathematics teachers implementing an integrated STEM curricular unit, we aim to answer the following research questions: How and why do high school mathematics teachers adapt when experiencing technological issues during an integrated microelectronics, engineering, and mathematics curriculum unit? How do these adaptations help students reengage in the curriculum? To address the research questions, researchers analyzed data from the implementation of an integrated microelectronics and engineering curriculum unit in two high school mathematics classrooms. This research is characterized as a qualitative study comparing multiple, embedded cases with each classroom representing one bounded case [21]. The details of the curriculum unit, data collection, and data analysis are expanded in this section along with justification for the chosen methods.

Context

As part of a microelectronics workforce development effort, teachers and researchers co-developed integrated engineering curricula intending to expose K-12 students to microelectronics contexts, content, and career paths. Of the 13 total units developed, the one chosen as the focus of this study was designed to replace two to three weeks of regular pre-calculus instruction and addresses standards related to continuity, extrema, data analysis, and engineering design. This particular unit, titled “Stressed Out”, consisted of eight lessons, each designed to be taught in one or two 50-minute class periods. It was chosen as the focus of this study because of the varied technological issues experienced by both teachers and students during implementation. In this unit, students worked through a real-world problem in teams by utilizing stages of the engineering design process to design a stress-intervention method for a client.

To be able to address the criteria and constraints given by the client, the students learned about intercepts, extrema, and continuity. Then later in the design process, students worked in groups, utilizing their knowledge of these mathematical concepts to justify their design decisions. Additionally, the curriculum unit was designed to introduce microelectronics as students learned about the client’s problem and generated potential solutions. To develop a successful stress-intervention method, the client required that students include pulse sensors connected to a codable micro:bit that could be used to monitor the intended end users. In doing this, the students learned about and utilized the micro:bit by measuring and analyzing resting heart rate data which could be used as evidence later on in the design process. Because the curriculum was designed to be implemented in pre-calculus classes, prior experience with coding was not assumed and pre-written codes were embedded in the curriculum unit. These block-based codes could be adapted to specific design choices and student contexts. In an effort to develop a flexible curriculum to meet a variety of student interests, multiple stress-related contexts (i.e., test anxiety, sports, gaming) were provided for students to choose.

Researcher-Teacher Partnership

Two teachers implemented the curriculum unit three days apart. They both participated in a weeklong curriculum-writing workshop during the summer, two months prior to implementing the unit. During this workshop, the teachers role-played as students while the researchers (acting as the teachers) demonstrated a science-content focused, engineering design-based curriculum unit. This let the researchers model how the curriculum unit should be designed and delivered, using an engineering design framework. During this demonstration, the researchers modeled a curriculum outside of the teachers’ content area, but included examples of microelectronics so that the teachers could integrate these methods and framework to their own content area. It is important to note that teachers did not receive actual instruction of the pedagogies involved in implementing specific technological devices in their classroom (i.e., the pedagogy was merely implicit in this modeling demonstration). The teachers worked with a researcher to develop the mathematics unit implemented in this study.

Case Descriptions

This is a multiple embedded case study with two cases. This research design reflects the concept of theoretical replication [21] because we anticipate the same integrated curriculum will be adapted on the spot by each teacher to fit the learning needs of their students. Each case is described below and includes one classroom per teacher indicated by their given pseudonym. The two classrooms are in the same high school in a small midwestern city. Both teachers implemented the unit in one of their pre-calculus classes.

Case 1: Nicole's classroom included 17 students ranging from 11th to 12th grade. This class met every day for 45-minute periods. Nicole has taught a few introductory engineering-related lessons in the past but has no experience with microelectronics or programming. Nicole's class worked in five teams of 2-4 students throughout the engineering design process.

Case 2: Laura's classroom included 28 students ranging from 10th to 12th grade. This class met in a typical block schedule, every other day for an hour and a half. Laura has a background in computer science but no experience teaching engineering or microelectronics. Her class worked in seven teams of 4 students throughout the engineering design process.

Analysis

The data generated for this study included whole classroom video in which the teacher audio was captured. In both cases, the teacher and students can be seen interacting and having many conversations throughout the lessons. As the types of activities that the students were working on varied, so did the modes of instruction. The teachers both interacted with the student design teams as well as with the whole class throughout the unit. Although we also captured video data of two target student groups in each case, whole classroom video was analyzed for this study since most of the evidence needed to be able to answer the research questions could be found through a holistic lens of classroom engagement. Constant comparative analysis was used to jointly code and analyze the video data to better compare across the two cases. We chose to utilize the constant comparative method as described by Glaser [22] because code generation and data interpretation across the two cases was more easily compared one lesson at a time. By this we mean that the researcher watched and analyzed a lesson in the unit taught by one teacher and immediately analyzed the same lesson taught by the other teacher. Within each case there are two embedded units of analysis [21], the teacher and the students. The main focus for the researcher analyzing the video data was the connection between the student engagement and the teacher actions. In the examples provided in the results section, Nicole's students will be identified using letters and Laura's students will be identified using numbers to help differentiate between the cases.

The following table includes descriptions of codes used when analyzing the whole classroom videos. A constant comparative method [22] was used alternating between the two cases in an attempt to identify differences in teacher adaptations for each lesson of the curriculum unit. A few of the original codes were chosen based on observing the teachers while collecting video data however, the rest were generated during the first pass through the videos while focused on the teacher adaptations to the curriculum unit in moments of technological failure and student frustration.

TABLE I Description of each code used while analyzing classroom videos

Code	*Description*
Sensor	Pulse sensor was inconsistent or broken
Code	Code did not work as intended or required debugging
Micro:bit	Issues with hardware like the micro:bit or wires

Website	Issues accessing links, accounts, or coding website
Knowledge gap	Teacher could not solve student technology related problem
Teacher frustration	Teacher showed signs of frustration
Adapting to shift	Teacher shifted focus away from the technological issue to something else
Adapting to ignore	Teacher had students ignore the technological issue and continue
High engagement	Signs of high student engagement
Low engagement	Signs of low student engagement
Student frustration	Student showed signs of frustration

Limitations

By focusing on signs of engagement for the students overall, we limit our ability of to understand how specific students or groups of students may engage or disengage compared to the average student in the class. In the future, analysis of target group data, including student artifacts, could help capture deeper evidence of student social-behavioral, affective, and cognitive engagement throughout the unit. Moreover, the case study methodology cannot be used to generalize due to the nature of a small-N sample size [21]. The data for this project was collected by multiple researchers during different days of class, potentially reducing consistency. Nevertheless, the research team routinely met to discuss their experiences and reconciled emerging inconsistencies in order to maintain consistent data collection methods.

Results

In both classrooms, there were a variety of technological issues experienced by the teachers and students. Specifically in lesson four, two problems were found across the cases. First, students were introduced to the sensor they needed to incorporate into their designs. When students attempted to capture resting heart rate, measurements were not consistent due to high sensitivity of the device to movement. Second, as teams planned out and built their designs for testing, some groups experienced issues with the micro:bit starter codes they were given. Depending on design decisions, students had to edit values in some of the block-based code. If groups did not identify this issue, the micro:bit did not function as the students intended. Malfunctioning micro:bits ranged from emitting a loud beeping noise to displaying the wrong information with LEDs. Additionally, a few of the internet links provided to students as video examples for developing testing procedures were blocked on student devices. Beyond lesson four, these technological issues occurred sporadically as the students continued to get experience using the devices and progressing in the engineering design process.

Most instances of high engagement occurred most at the beginning of the curriculum implementation and during hands-on activities, while most instances of low student engagement occurred in lessons in which students were working with the micro:bit and pulse sensor. Patterns of low student engagement were noted and occurred in three main forms.

The first form of low student engagement was demonstrated by students giving up or switching tasks. This form was often accompanied by signs of student frustration with technological malfunctions. An example can be seen in the following observation from Nicole’s class when one group of students could not get their micro:bit to show heart rate in the data display window.

> Nicole: “Are we seeing data?”
>
> Student A: “No it’s not […]”
>
> Student B: “We’re dying” […]
>
> Nicole: “We tried downloading it again, right?”
>
> Student C: “Yeah we’ve downloaded it twice.”
>
> Nicole: “And we think it’s hooked up correctly?”
>
> Student B: “Yeah”

The second form of student disengagement can be characterized by groups playing with various testing methods (i.e., games, iPads) without collecting data or assessing the functionality of their design. At first glance, this looks like engagement in their group but was unrelated to the task at hand.

The third form of disengagement included chatting within and between groups about topics unrelated to the design project, interrupting the teacher with something unrelated to the content, or taking out their phones. It’s worth noting that this form of disengagement is commonly experienced by high school teachers in all subject-matter areas and curriculum models. The teachers often addressed these moments using classroom management techniques, policies, and norms they had previously established with their students.

In both classrooms, teachers altered the curriculum in the moment when students disengaged while experiencing technological issues. Most of the time before altering the curriculum, teachers tried to fix or debug the devices and code. There were also times they anticipated disengagement due to technological malfunction, especially in later lessons. The four ways teacher actions generated pathways to student reengagement included: normalizing technological failures, focusing on the development of a process instead of a product, focusing on the process of testing and evaluation, and encouraging reflection in engineering notebooks.

Normalizing technological failures

Both teachers acknowledged the temperamental nature of the devices the students were using multiple times and connected to the real-world in which technological devices malfunction. Nicole told students to assume the client has access to more high-quality tools. This is exemplified in the following quote: “let’s pretend like the micro:bit is doing exactly what you want it to do”. Laura told students to move on and ignore the little malfunctions with their devices. The following discussion serves as an example of how Laura adapted to student frustration with the pulse sensors.

Laura: “Are you guys still playing around with the code?”

Student 1: “We have to change our code because [...] we can’t do maximum and minimum, we have to change our goal”

Laura: “Okay.”

Student 1: “So we’re gonna change it to like, so it’s gonna be the same like if it’s above eighty or below eighty”

Laura: “Okay, that’s fine. Yeah!”

Student 1: [...]

Laura: “That’s fine, that works! That’s why it’s still testing, we’re still in the testing procedure so that’s fine.”

Student 1: “Um yeah and then this thing [gestures to heart rate sensor] is super finicky so it’s gonna be hard to get it exactly right.”

Laura: “Yeah we just have to assume like in a perfect world it wouldn’t be, so [...] just going through the procedure seeing this is what would happen in real life.”

Focusing on the development of a process instead of a product

In Nicole’s class, instead of having students test each other’s physical devices and code, she had teams rotate around and test each other’s method for stress intervention. As students assembled their devices and downloaded the code, there were issues with the pre-written settings. Nicole tried many times to debug the students’ codes but did not have the expertise needed to solve the problem. After working with each group and realizing most of the students were showing signs of frustration the teacher addressed the class:

Nicole: “Has anyone been able to successfully make their micro:bit do what it’s supposed to do? […] Raise your hand if you’ve been successful”

(no one raises their hand)

Nicole: “So, when you get something to work let me know. We might be spending a little more time on this but that’s okay because we want to make sure everybody’s got down what they’re supposed to be doing.”

After another few minutes of letting students play around with the code the teacher shifts the direction of the activity:

Nicole: “So on the testing procedure I think we have a couple issues with the micro:bits or whatever so let’s just think for just a minute. What is your testing procedure? Let’s make sure it’s clear. So what do you want somebody to do when they are trying to test? So, whether the micro:bit actually works or not, what is the procedure that you want them to follow? Do you want them to watch one of those video clips? […] What is it you want somebody to do so that they can test to see if everything works? So whether the micro:bit actually works, what is the procedure that you need somebody to do when they get to your group? […] Once we get that procedure down then we can work on these details of getting it to work but we gotta know our thinking process first. […] What do we want somebody to do when we’re going to see if what we’re picking for our intervention is going to help them? How are we going to do that?”

Student E: “But our testing procedure is based on […] using the heart monitor to watch the video, how do we know the heart rate if we don’t […]”

Nicole: “Well, let’s just say what do we want them to do. Then we’ll try to get the micro:bit to do that. Okay? […] Just come up with the plan. What would the plan be?”

This example illustrates how students were focused on getting the device to work, often accompanied with frustration. After Nicole spent time working with groups to debug the device and did not come up with a solution, she redirected the students to think about developing their procedures. This was a core component of the design challenge students would need to incorporate into their solutions. Nicole emphasized development of their groups’ stress intervention methods outside of “the details of getting [the device] to work”.

Focusing on the process of testing and evaluation

In Laura’s class, students were given more time than planned to develop and carryout a testing procedure for their stress-intervention methods. When students encountered issues, the teacher prompted them to forget the technological mishaps, refine their testing procedure, and redesign their intervention method based on what they think they would need to change if everything was functioning as intended. The following example is a continuation of the discussion Laura had with the student about the pulse sensor being finicky.

Student 1: “Um yeah and then this thing [gestures to heart rate sensor] is super finicky so it’s gonna be hard to get it exactly right.”

Laura: “Yeah we just have to assume like in a perfect world it wouldn’t be. So [...] just going through the procedure seeing this is what would happen in real life. Um and then whatever one you want to do, I have sudoku or I have like I said crossy road is also kind of a strategy game.”

Student 1: "And that one might even make you more stressed and also it's a lot more simple so we could [...]"

Here we can see how Laura redirected the frustration the group was showing with the device and focused instead on options they could use for their testing procedure.

Encouraging reflection in engineering notebooks

Both teachers encouraged students to write down what worked and what didn't work in their engineering notebooks. Throughout the unit they emphasized reflection.

After coding and analyzing the data, we noticed that it was difficult to make connections between teacher adaptations and student disengagement because we were not able to identify WHY teachers made changes. In other words, we identified moments of adaptive performance, or behaviors of the teachers but needed more information to understand teacher adaptive expertise. We expanded the data in our study to include teacher self-reflections of the findings. Segments of these vignettes will be included in the discussion below to help clarify the thought process behind the actions taken by each teacher.

Discussion

Throughout the implementation of the integrated curriculum unit in the mathematics classrooms, both teachers added or shifted content when experiencing technological issues. Recognizing these teachers as adaptive experts in their domain can help to understand how and why they demonstrated adaptive performance [17]. Both teachers made changes based on anticipating or reacting to student behavioral or agentic engagement [11-12]. Although both teachers approached on the spot adaptations in different ways, they explain how they prioritized student engagement, communication, and knowledge of processes. Both teachers demonstrated elements of adaptive expertise especially *flexibility* [11]. Similar to disengagement from moments of boredom and hopelessness [6] the teachers noted moments of student frustration as triggers for adaptation. The following quotes help us understand why the teachers normalized technological malfunctions for their students:

> "I sensed frustration from the students. Many of my students have wearable devices that provide accurate information and I sensed frustration that the heart rate monitors that we used were not accurate." – Nicole
>
> "Since my class for the unit were the accelerated kids of the school, I knew they couldn't be fooled into thinking that the readings were very accurate. Also, as a teacher, I want to always be transparent with my students." – Laura

The teachers both acknowledged the temperamental nature of the devices for different reasons but their actions were rooted in *deep-level understanding* of their students' perspectives and the topic emotions related to the design challenge [12]. Nicole explained how the shifts she made were due to wanting the students to have a "meaningful" experience and to have the chance to "communicate [their] processes to each other". Laura explained how she made shifts to "take frustration out of the equation” because she “didn’t want our lack of quality sensors to get in the way of the whole experiment”.

Time constraints were a factor present in both cases. The teachers demonstrated previous *deliberate practice* as mathematics teachers as they acknowledged when they had to move on even if students could not get a device to work. Nicole explained her decision to shift focus to the development of a stress-intervention process because she “knew that students were frustrated with devices and that we were up against a hard deadline to end the unit”. It is worth noting that a technological malfunction that requires one-on-one attention from the teacher could impact a 45-minute class like in Nicole’s schedule to a greater degree than an hour and a half class like in Laura’s schedule.

When comparing between the two teachers, the difference in experience with the technology may have contributed to the ways in which each teacher adapted to technological failures. As opposed to Laura, Nicole has experience designing and teaching engineering activities but no background in computer science or coding. Their unique content-area backgrounds and previous experiences contribute to their demonstration of adaptive expertise specifically in elements of *deliberate practice* and *deep-level understanding* [11]. The differences across the two cases illustrate how and why mathematics teachers make various adaptations when implementing an integrated engineering and microelectronics curriculum unit.

Conclusion

As in-service teachers prepare their students to be successful in the future workforce, we need to consider how to best help teachers adapt to new expectations. Mathematics teachers tend to face different pedagogical norms that science, technology, and engineering teachers which makes a more explorative curriculum unit difficult to integrate in their classrooms [5]. This research study provides an example of linking the engineering design process with mathematics but more support needs to be provided to future teachers working to integrate unfamiliar topics like microelectronics in their typical content area.

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