Building Teacher Self-Efficacy Through Practice-Based Professional Development in Microelectronics Education

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Abstract

This research paper examines a Community of Practice (CoP) for high school teachers integrating microelectronics, computer science, and engineering concepts into their classrooms. While efforts to integrate microelectronics (ME) into K-12 education are gaining traction, there remains a lack of research on how teachers are prepared and on the outcomes of professional development (PD) programs focused on emerging technologies, such as ME. Specifically, in the areas of teacher self-efficacy (instructional readiness & self-doubt) and content knowledge (content understanding), there is a need for closer attention. The research team recruited five local high school teachers to participate in a three-day workshop hosted by a university. Each day concentrated on a specific lesson within the unit involving simple circuits, breadboarding, logic gates, and other foundational concepts. Teachers engaged in each lesson to strengthen self-efficacy and content knowledge in preparation for future classroom implementations. The teachers followed an engineering design approach by designing, building, testing, and refining their circuits. Data for this study included open-ended responses from pre- and post-workshop surveys, daily reflections during the summer workshop, reflections collected during two additional PD sessions in the fall 2025 semester, and a post-implementation survey. The surveys were guided by the Teachers' Sense of Efficacy Scale (TSES) framework and by additional open-ended questions developed by the research team. Responses were analyzed qualitatively to examine teachers' perceptions of instructional self-efficacy and content knowledge. The objective of the study is to conduct a multi-method qualitative analysis to evaluate how participation in the workshop and additional PD sessions influenced teachers' perceptions of their instructional self-efficacy and content knowledge when preparing to implement microelectronic lessons. Preliminary findings suggest that teachers with limited background in microelectronics reported increased self-efficacy and content knowledge following participation in the curriculum workshop. These findings highlight the importance of structured, practice-based professional development. This study contributes to faculty development research by examining how structured, practice-based PD models can build teacher self-efficacy and content knowledge, thereby informing professional learning frameworks that help educators implement and integrate new technologies in their classrooms. In turn, this allows teachers to incorporate new content into their classrooms, encouraging students to learn more about microelectronics. This paper will be presented to facilitate discussions on teacher professional development regarding their self-efficacy and growth in content knowledge in microelectronics education.

Keywords: Communities of Practice (CoP), Teacher Self-Efficacy, Microelectronics Education, Teacher Professional Development, Practice-Based Learning

Introduction

Background

A Community of Practice (CoP) is commonly defined as a group of individuals who share a passion or concern for a particular topic and extend their knowledge and expertise through ongoing interaction [1]. This collaborative framework is built upon three core characteristics: a shared domain of interest, a community of engaged participants, and a body of shared practice [2], [3]. Each member of a CoP possesses a common commitment to the shared domain and engages regularly to exchange ideas, offer support, and cultivate a sense of belonging [4]. The community element emphasizes collaborative relationships where participants learn from and with one another [1].

The theoretical foundations of CoPs align with constructivist and sociocultural learning theories [5], [6], [7]. These theories emphasize that learners construct knowledge through social and contextual experiences [8], [9]. Situated learning theory, introduced by [6], supports these collaborative CoP environments. They discussed how knowledge emerges from active participation in meaningful activities within authentic social and cultural contexts. This participation reflects learning as a cognitive and social process, where learners build skills and confidence tied to context, activity, and identity over time [6], [10], [11]. However, CoPs are not genuinely equitable; prior research has shown that participation can be uneven and shape power dynamics, which enables privileges for some members while marginalizing others, particularly newcomers [12], [13].

In educational contexts, CoPs offer environments where new pedagogical ideas and approaches can be developed through sustained participation, leading to classroom innovations [14], [15]. Teachers frequently exchange valuable insights and experiences, aiding and informing fellow teachers for future implementation practices and strategies [16]. Within a CoP, these exchanges occur as part of ongoing mutual engagement around a shared instructional purpose rather than as isolated information-sharing. Identity formation is central to [1]'s theory of learning: as individuals engage in shared practices, they construct new identities based on their roles and positions within the community, which shape how teachers interpret new ideas, enact instructional practices, and participate in collaborative problem-solving.

In the K-12 setting, participating in a CoP can improve teachers' STEM instructional capacity and support identity development [17], [18], [19]. Researchers further suggest that participating in a CoP can improve high school teachers' self-efficacy for STEM instruction by creating ongoing peer engagement beyond a week of workshops [18]. [20] validated this idea by developing the teaching engineering self-efficacy scale (TESS). This scale identifies key dimensions of teachers' confidence in engineering pedagogy, student engagement, and content knowledge. Through CoPs, this support can better develop teachers' readiness and effectiveness to teach in K-12 engineering classrooms. These collaborative structures are especially valuable and emergent in engineering and computer science (CS) education [11], [18], [21].

In engineering and CS education, CoPs can take the form of faculty-led professional development (PD) initiatives, research labs, makerspaces, or online networks [22]. Learner's co-construct knowledge in these environments and apply it to new contexts [23], [24]. Additionally, these organizations can compensate teachers for their time and provide classroom infrastructure and equipment to retain faculty beyond individual workshops [25], [26].

Recent research by [27] shows how CoPs can be designed to support interdisciplinary learning in CS classrooms. Their study implemented two instructional designs: one was where students participated in learning through traditional lectures and problem-solving activities, and the other was where dedicated instructors from both education and CS co-taught the course. Both models leveraged CoP principles to enable collaboration. Their findings indicated that the co-instructor model proved more effective in assisting CS students to adopt and apply theories and practices through mentor-guided discourse. These results highlight the role that CoPs can play within the CS discipline.

In microelectronics (ME) education, some communities focus on integrating tools such as Micro: bit, Arduino, or Raspberry Pi into secondary STEM classrooms [28]. In these CoPs, teachers exchange lesson plans, demonstration strategies, and classroom management techniques for these project-based electronic-focused lessons. These microelectronic-focused communities depict how domain-specific CoPs can support teachers working with emerging technologies and complex CS and engineering topics. ME education presents challenges in K-12 contexts due to its interdisciplinary nature, technical demands, and limited opportunities for sustained teacher preparation. The Scalable Asymmetric Lifecycles Engagement (SCALE) K-12 initiative addresses these challenges by supporting teachers through structured PD opportunities [29]. These experiences allow for CoPs to form around curriculum implementation, instructional problem-solving, and peer support in K-12 classrooms.

Research Question

To better understand the impact of collaboration on teachers', we are asking the following research questions:

> **RQ1:** How does participation in a summer PD program influence teachers' self-efficacy and content knowledge growth in implementing collaborative ME lessons?
> **RQ2:** How do these perceptions shift over time as teachers engage with curriculum and peer support?

Methods

Design

This study used a multi-method case design to analyze how teachers' self-efficacy and content knowledge developed over time as they participated in a CoP focused on ME education. Both Likert-scale and open-ended data were collected at multiple points to capture changes in teachers' beliefs and instructional experiences as they moved from PD into classroom implementation.

Data collection occurred during three phases: (1) a three-day summer PD workshop (Schedule in Appendix A), (2) continuing two PD workshops during the fall semester, and (3) post-implementation reflections for the teachers who taught the curriculum. During the summer workshop, participants completed a pre-survey at the start of the first day, daily reflection prompts at the end of each workshop day, and a post-survey on the final day. During the fall semester, teachers completed a post-workshop survey after an additional PD session on an expansion car kit. A second asynchronous PD was distributed at the end of the fall 2025 semester, during which teachers reflected on their implementation of the curriculum or on preparations for future implementation. Data was collected at five to eight time points (pre-survey, three daily reflections, post-survey, post-PD1 workshop, PD2 reflection, and post-implementation reflection), allowing for a deep analysis of change across both the summer workshop and fall instructional period.

Although quantitative survey data were collected at multiple points, the analysis was primarily qualitative, using repeated reflections to examine how teachers' self-efficacy and content knowledge evolved over time. Each teacher is treated as an individual case, enabling cross-case comparisons of learning within the CoP. Quantitative self-efficacy measures were used to contextualize these qualitative findings rather than to conduct a statistical analysis.

Context

This study took place with a CoP formed around the *Guardians of the GRID* curriculum, a project-based ME and CS unit developed through the SCALE K-12 program [30]. During the summer workshop, teachers learned about the *Guardians of the GRID* unit through direct instruction, peer collaboration, and hands-on activities in physical computing and electronics. Teachers worked with Micro: bits, breadboards, LEDs, resistors, and other electronic components included in their take-home kits. The fall PD sessions extended this work through the use of Micro: bit car expansion packs and reflection on future or past lesson adaptation and implementation, depending on the teacher's schedule.

Participants

Five high school CS teachers participated in the CoP. Each recruited teacher was responsible for teaching CS at their school and planned to implement the *Guardians of the GRID* curriculum during the 2025 - 2026 academic year. The teachers were recruited through word of mouth or forms to participate in this study. Participants entered the study with varying backgrounds in content knowledge and instruction in CS/engineering. All teachers received a full set of curriculum materials during the summer and fall PD workshops. Each participant in the workshop consented to participate at the start of the study.

Four participants taught in public high schools, and one taught in a private high school, all near a large Midwestern university in the United States. One school served grades 8-12, while the other schools served grades 9-12. Teacher T1 (Stephanie) taught at a public 9-12 high school but left the study after the summer session due to her departure from the school. Teacher T2 (Joseph) taught at a public 8-12 school and continued through both fall PD sessions. T2 is also a co-author of the *Guardians of the GRID* unit and has been with the project for over a year. He has also piloted the unit three times before the summer workshop to share improvements and authentic pedagogical approaches with the teacher partners. Teacher T3 (Mark) taught at a private 9-12 school but left the profession midway through the fall semester. Teachers T4 (John) and T5 (Jessica) taught at public 9-12 schools and participated in the PD1 and PD2 sessions. Jessica (T5) participated in PD1 on her own schedule, since she was dealing with a family emergency. She also completed PD2, discussing her future implementation approaches for the 2025 - 2026 school year. T1, T3, T4, and T5 are classified as teacher partners, who are new to the curriculum, while T2 is categorized as a teacher fellow; an educator already associated with the project.

Teachers were recruited through online flyers distributed to local schools and through word of mouth from members of the research team. To sustain participation throughout the year, teachers were provided with classroom materials associated with the microelectronics curriculum. In addition, completion of the PD activities was required for teachers to receive their stipend and PD hours. In total, five local teachers (n = 5) participated in the summer workshop and the fall PD sessions (n = 3); this was the sample size for this study.

Pseudonyms were used for all participants to protect their confidentiality. Teachers are referenced throughout the paper using both an identifier (T1-T5) and a pseudonym (either assigned or selected). The use of pseudonyms does not correspond to the level of participation, teaching status, or outcomes in the study.

Data Collection

Data was collected through a five to eight (listed in design) paper-based surveys and reflection instruments administered during the summer and fall semesters of the study. The pre- and post-surveys included [31]'s 24-item Teacher Self-Efficacy Survey (TSES) and 14 Likert-scale items focused on ME and physical computing instruction [32], [33]. The pre-survey included five open-ended questions, and the post-survey included three. Daily reflections included two open-ended questions on the first day and three on subsequent days. With the exception of the TSES, which is valid and reliable, all items were developed by the research team to align with curriculum and professional development goals.

Coding

Open-ended surveys and reflections were analyzed using an inductive thematic coding scheme aligned with constructs of content knowledge and instructional self-efficacy. A Ph.D. candidate developed an initial coding framework based on the responses. Once complete, the principal investigator reviewed the coding scheme to ensure alignment with the research questions and conceptual framework, thereby establishing face validity. The final codebook consisted of two overarching domains of Instructional Self-Efficacy (subcodes: Instructional Readiness & Self-Doubt) and Content Knowledge (Subcode: Content Understanding), as shown in Figure 1.

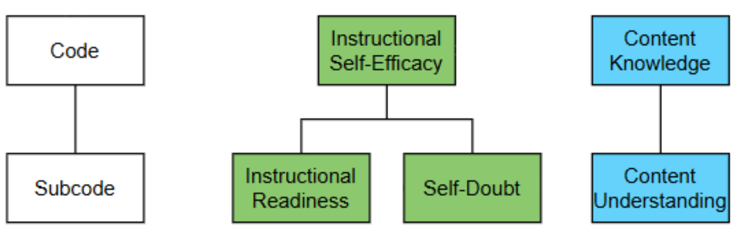

Figure 1. Overall codes and subcodes

Content Knowledge was coded through teachers described understanding of ME concepts, including circuits, logic, and troubleshooting. Instructional Self-Efficacy was reflected in teachers' self-reports of instructional readiness and in expressions of self-doubt about teaching ME. Each code was defined using explicit inclusion criteria and supported by an example response to promote consistency in coders' interpretation.

All open-ended (100%) responses were coded by the primary researcher. To establish interrater reliability, a second researcher independently coded a random 20% of the dataset [34]. Both researchers discussed discrepancies and applied final codes. The average agreement was 97.3%, calculated by averaging the agreement for each code. Cohen’s kappa was calculated in SPSS to assess interrater agreement. Interrater reliability was assessed using Cohen’s kappa for each binary code across 38 responses. Agreement was almost perfect for Instructional Self-Efficacy ($k = .94$) and Instructional Readiness ($k = .93$). Agreement was substantial for Content Understanding ($k = .65$). The Self-Doubt code did not occur in the interrater reliability dataset, and therefore, kappa could not be computed.

After the initial coding of each response, the two researchers collaboratively evaluated each teacher’s trajectory across checkpoints using two four-level rating scales: Instructional Self-Efficacy and Content Knowledge, shown in Table 1. The Instructional Self-Efficacy scale captured teachers’ confidence in planning, implementing, and adapting ME lessons. The Content Knowledge scale captured teachers' conceptual and applied understanding of microelectronic concepts. Each teacher’s response at each data collection point was assigned a score from 1 (low confidence or minimal understanding) to 4 (high confidence or comprehensive understanding). When a response did not provide sufficient evidence to assign a level, the prior checkpoint’s rank was carried over to maintain continuity in each teacher’s story.

Table 1. Coding scale trajectory for self-efficacy and content knowledge

	Coding Scales	
#	Instructional Self Efficacy	Content Knowledge
1	Low confidence/uncertainty	Awarenss of concepts, little familiarity
2	General teaching confidence	Basic understanding of tools/concepts
3	Confidence in planning and preparing ME lessons	Applied understanding through hands-on use
4	Confidence in implementing and adapting ME lessons	Comprehensive understanding supporting instruction/troubleshooting

Analysis Procedures

After the summer workshop, an undergraduate researcher scanned and uploaded the paper responses from each data collection item. The Likert-scale questions were typed into a Microsoft Excel spreadsheet. Open-ended responses were transcribed into a Microsoft Word document and combined with the quantitative data in a single spreadsheet. Each participant was anonymized, with all identifiable information removed.

The Ph.D. candidate researcher organized the data across multiple pages within a single document, separating each section of each data collection item. The TSES was organized into three efficacy sections: student engagement, instructional strategies, and classroom management.

The quantitative second part of the pre-and post-surveys was separated into motivation, instructional strategies, professional identity, general collaboration, and future applications.

All open-ended responses were organized chronologically across five to eight data collection points to create a longitudinal timeline for each teacher. Each item was coded using an inductive coding scheme to examine changes in self-efficacy and knowledge of ME content over time. Each response was coded using a binary system (0 = theme absent; 1 = theme present), allowing multiple themes per response. Qualitative scales for self-efficacy and content knowledge were assessed for each teacher by the researchers to examine trajectories. The open-ended qualitative responses were the primary focus of this paper's analysis.

Results

For each response, open-ended and Likert-scale, a researcher coded responses according to the developed thematic coding scheme, and data summaries were compiled for each teacher. The summaries include the following information for each teacher's checkpoint: the thematic subcodes associated with the response, self-efficacy, and content knowledge scores, and direct quotes from the teacher's open-ended responses to illustrate the numeric ratings. The summary tables for T1-5 are depicted in Tables 3-7, respectively.

Teacher 1 (T1 – Stephanie)

Stephanie's (shown in Table 2) instructional self-efficacy increased from a 2 (general teaching confidence) at the pre-survey to 4 (confidence in implementing ME lessons) by the end of the workshop. Her content knowledge remains at an applied level (3) throughout. Early in the workshop, she described herself as feeling "sometimes nervous if I don't feel like a master of the content." By the final survey, she stated, "I plan to host workshops with girls who code... I will use these topics and lessons." She also noted specific tools and activities (e.g., "I understand how circuits work and can share that with students"). Although she demonstrated an applied understanding of ME throughout the workshop, she did not express comprehensive mastery.

Table 2. Data summary for T1 (Stephanie)

T1	Codes			Quotes	
Time	Efficacy	Content	Subcodes Present	Self-Efficacy Quotes	Content Knowledge Quotes
Pre-Workshop	2	3	Content Understanding, Self-Doubt	"Excited for new experiences, sometimes nervous if I don't feel like a "master of the content... [My biggest concern about teaching ME is] feeling totally confident of the entire content"	"[I have used] Robots Lego EV 3 - microbits - Sphero Bolt and microbit kits"
Daily Reflection 1	2	3	Content Understanding, Instructional Readiness	"[I feel most confident] Creating programs w/microbits creating simple circuits."	
Daily Reflection 2	3	3	Instructional Readiness	"[I feel confident with] all, I will modify [the content] to my classroom"	"The 'engineering' piece will be new for me ... Coding problems will come up but I feel very comfortable addressing these issues."
Daily Reflection 3	3	3	Content Understanding, Instructional Readiness, Self-Doubt	"I need more practice... [but I feel most confident with] the sewing kit! Awesome acitivity for so many ages."	"[I feel most confident with] The sewing kit! Awesome acitivity for so many ages."
Post-Workshop	4	3	Content Understanding, Instructional Readiness	"I plan to host workshops w/ girls who code. Workshops already happen, but I will use these topics/lessons."	"I understand how circuits work and can share that with students."

Teacher 2 (T2 – Joseph)

Joseph (shown in Table 3) entered the workshop with high instructional self-efficacy and content knowledge, both at level 3. His instructional self-efficacy increased to 4 by the end of the first day and remained at that level throughout the workshop, PD sessions, and post-implementation. His content knowledge increased from 3 to 4 by day 3, where it remained at that level through the post-implementation reflection. Early in the workshop, Joseph described his confidence by stating, "Time teaching CS and Engineering has given me the experience of reacting and improvising questions in a learning environment." He later described, "[I feel most confident in] demonstrating circuit types. Circuit debugging and troubleshooting." By the end of the workshop and throughout the PD opportunities, he continued to express confidence and applied understanding of the content (e.g., "I feel comfortable self-supporting on this, overall.").

Table 3. Data summary for T2 (Joseph)

T2	Codes			Quotes	
Time	Efficacy	Content	Subcodes Present	Self-Efficacy Quotes	Content Knowledge Quotes
Pre-Workshop	3	3	None	"Time teaching CS and Engineering has given me the experience of reacting and improvising questions in a learning environment."	"I've been teaching with physical computing for five years now and love finding new applications."
Daily Reflection 1	4	3	Instructional Readiness	"[I feel confident in] any (All), as I have implemented before."	
Daily Reflection 2	4	3	Instructional Readiness	"[I feel confident in] any/All. This was my fourth time through the unit!"	
Daily Reflection 3	4	4	Content Understanding, Instructional Readiness	"[I feel most confident in] demonstrating circuit types. Circuit debugging and troubleshooting."	
Post-Workshop	4	4	None	"Absolutely, [I feel more confident.] I'm excited to learn more for this community of practice."	"I'm planning to work a lot more with fabrics and circuits and copper tape circuits."
Professional Development 1	4	4	Instructional Readiness	"[I feel] No more or less confident , but definitely more excited!! Appreciate the combination of presentation and hands-on!"	"[I plan to implement more] More mini robotics for sure!!"
Professeional Development 2	4	4	Content Understanding, Instructional Readiness	"I feel comfortable self-supporting on this, overall."	"The real nitty-gritty here is knowing the various solid ways to code a lock ... so that you can give students meaningful coding assistance. There is NO substitute for coding your own lock. "
Post Implementation	4	4	Instructional Readiness	"I think I'll make an extended context piece about the cybersecurity elements. "	"The connections related to manufacturing were solid. I'm working to refine my student conversations regarding cyber security and international relations connections."

Teacher 3 (T3 – Mark)

Mark (depicted in Table 4) began the workshop with an instructional self-efficacy score of 2 and a content knowledge score of 2. His instructional self-efficacy increased to 3 by the end of day 1. His score briefly returned to a 2 at the conclusion of day 2, where it increased to 3 and 4 by the end of the workshop. Mark's content knowledge increased from 2 to 3 over the course of day 1 of the summer workshop. His content knowledge score remained at a 3 throughout the rest of the workshop. Early in the workshop, he expressed both interest and uncertainty, stating, "[I am] excited... I enjoy demystifying technology... [but my biggest concern is a] lack of familiarity with ME." On day 1, he reported confidence, noting, "[I feel confident on the] introductory + teaching about the Micro: bit showing how changing the code changes the output." During day 2, he continued to reference both confidence and challenge, stating, "I feel most confident using the Micro: bit... [but] the challenges right now for me would be the coding aspect." By the end of the workshop, Mark reported high instructional self-efficacy, stating, "Now after this workshop, I feel confident integrating ME into my classes."

Table 4. Data summary for T3 (Mark)

T3	Codes			Quotes	
Time	Efficacy	Content	Subcodes Present	Self-Efficacy Quotes	Content Knowledge Quotes
Pre-Workshop	2	2	Content Understanding, Self-Doubt	"[I am] excited, I like teaching networking to students. I enjoy demystifying technology... Being asked to teach ... That was a vote of confidence."	"[My biggest concern is that I have a] lack of familiarity with ME."
Daily Reflection1	3	3	Content Understanding	"[I feel confident on the] introductory + teaching about the Micro: Bit showing how changing the code changes the output on the Micro: Bit.	
Daily Reflection 2	2	3	Content Understanding, Self-Doubt	"I feel most confident using the MicroBit + using the website to do the coding for the micro Bit." "The challenges right now for me would be the coding aspect."	"I feel most confident using the MicroBit + using the website to do the coding for the micro Bit."
Daily Reflection 3	3	3	Instructional Readiness	"I feel good about the copper tape lesson + helping the kids work through it. I see the value in introducing these concepts + exposing the kids to this info!"	
Post-Workshop	4	3	Instructional Readiness	"I had very little experience with ME. Now after this workshop I feel confident integrating ME into my classes."	

Teacher 4 (T4 – John)

John (shown in Table 5) began the workshop with an instructional self-efficacy score of 2 and a content knowledge score of 2. His instructional self-efficacy increased to 4 by day 1, then decreased to 3 on day 2 and 3, and then increased again to 4 by the end of the summer workshop and throughout the first PD session. His content knowledge increased from 2 to 3 by the end of day 1 and remained at that level. At the start of the workshop, John conveyed both confidence and uncertainty, stating, "I do not have much experience with teaching engineering-based lessons beyond Micro: bits. I feel uncertain." By day 1, he reported increased confidence, noting, "I feel most confident in implementing Micro: bits into my classroom." Midway through the workshop, he repeatedly referenced his readiness to implement specific activities, such as "The first lesson using copper tape seems the easiest to implement." By the end of the workshop and into the car kit PD John continued to report high instructional self-efficacy and applied understanding of the content (e.g., "I plan to implement lessons with the bread boards and expand the use of the Micro: bits" and "Exposure and working through mock lessons have been very beneficial to my understanding and have contributed to my confidence"). For the last PD, John maintained high instructional self-efficacy and implementation plans but expressed some hesitation about using breadboards in his lesson.

Table 5. Data summary for T4 (John)

T4	Codes			Quotes	
Time	Efficacy	Content	Subcodes Present	Self-Efficacy Quotes	Content Knowledge Quotes
Pre-Worskhop	2	2	Instructional Readiness, Self-Doubt	"The progression I have seen in myself as a teacher, learner, and professional over the years have solidified the "I can" spirit. [but] I do not have much experience with teaching engineering-based lessons beyond microbits. I feel uncertain."	"I have led several lessons using microbits. I would say I have moderate experience."
Daily Reflection 1	4	3	Instructional Readiness	"I feel most confident in implementing micro:bits into my classroom. I am very excited to learn more about ME and 3D printing."	
Daily Reflection 2	3	3	Instructional Readiness	"I actually feel quite confident implementing the extensions with [Micro: bit] after having experienced some of its capabilities myself."	
Daily Reflection 3	3	3	Instructional Readiness	"The first lesson using copper tape seems the easiest to implement the two."	
Post-Workshop	4	3	Content Understanding, Instructional Readiness	"I plan to implement lessons with the bread boards and expand the use of the microbits " "Exposure and working through mock lessons have been very beneficial to my understanding and have contributed to my confidence."	
Professional Development 1	4	3	Instructional Readiness	"I plan to implement ME unit this semester."	
Professional Development 2	4	3	Instructional Readiness	"I ended up settling to implement the unit into my Spring semester, single section course."	"I anticipate programming with Micro:bit to go well ... wondering about utilizing the breadboards."

Teacher 5 (T5-Jessica)

Jessica (portrayed in Table 6) began the workshop with an instructional self-efficacy score of 2 and a content knowledge score of 2. Her instructional self-efficacy increased to 4 by the end of day 1, and remained at that level throughout the summer workshop and first fall PD. During the second fall semester PD, her self-efficacy score dropped to 3. Her content knowledge increased from 2 to 3 by day 1 and remained at that level. At the start of the workshop, Jessica stated, "Just the constant teaching of material makes me confident," and also noted, "I just want to make sure I completely understand everything." By day 1 and throughout the workshop, she consistently reported high confidence in implementing the lessons, by stating, "I feel confident about implementing the Micro: bits in my classroom." Across the workshop and PD sessions, she also demonstrated an applied understanding of the content: "This PD has given me some hands-on activities to supplement the content that I am already teaching."

Table 6. Data summary for T5 (Jessica)

T5	Codes			Quotes	
Time	Efficacy	Content	Subcodes Present	Self-Efficacy Quotes	Content Knowledge Quotes
Pre-Worskhop	2	2	Instructional Readiness, Content Understanding	"Just the constant teaching of material makes me confident."	"I just want to make sure I completely understand everything... We built small computers run off Raspberry Pi that ran Minecraft."
Daily Reflection 1	4	3	Instructional Readiness	"I feel confident about implementing the Microbits in my classroom. I already saw how it connected to content that I already teach."	
Daily Reflection 2	4	3	Instructional Readiness	"I feel confident in implementing this lesson in my classroom. The lesson had plenty of examples to go through to get things started."	"I think it will just take some time playing around with all the components and code available in Microbits. It will be beneficial to know what everything does."
Daily Reflection 3	4	3	Instructional Readiness	"The drawing with the copper tape activity was pretty straight forward and I think it would be pretty easy to implement."	"I think just doing the activities a few more times would be enough preparation."
Post-Workshop	4	3	Instructional Readiness	"Yes, I do feel more confident. I think that the hands-on activities helped increase my confidence."	"This PD has given me some hands-on activities to supplement the content that I am already teaching."
Professional Development 1	4	3	Instructional Readiness	"I will try to incorporate more microelectronic mini lessons."	"I think I just need more time testing things out. "
Professional Development 2	3	3	None	"I dont't think I need any support at this time."	

Discussion

The findings from this study incorporate the three-day summer PD workshop and a fall 2025 period that included mandatory PD sessions and a classroom implementation phase. Although all teachers were expected to participate across both summer and fall phases, participation varied: only one teacher (Joseph, T2) implemented the full ME curriculum, while others planned to implement in the spring, missed sessions or left the teaching profession. This structure allows examination of how instructional self-efficacy and content knowledge changed during the summer workshop and over the fall semester with curriculum expansions and peer support over time, aligning with the study's research questions.

Self-Efficacy Development from Summer Workshop

Across all five cases, teachers demonstrated increases in instructional self-efficacy from the beginning to the end of the summer workshop. Although all participants entered with general teaching experiences, several teachers, Stephanie (T1), Mark (T3), and John (T4), initially expressed self-doubt about their abilities to implement ME lessons. As the workshop progressed, these expressions of uncertainty faded and were replaced by statements reflecting excitement, confidence, and plans to utilize the curriculum in their classrooms. By the final day of the workshop, all teachers reported high instructional self-efficacy regarding ME instruction.

This shift aligns with prior work on teacher self-efficacy, which emphasizes the role of mastery experiences, collaborative peer interaction, and opportunities to practice instruction in building confidence for teaching new content [31], [35], [36]. The workshop was designed around these pedagogical strategies. Teachers built circuits, programmed Micro: bits, observed one another while troubleshooting, and discussed instructional strategies. The hands-on and collaborative nature of the workshop provided repeated opportunities for teachers to engage with ME tools and lessons, supporting overall growth in domain-specific instructional self-efficacy.

Content Knowledge Development from Summer Workshop

All teachers also showed growth in their ME content knowledge throughout the three-day workshop. While several participants had backgrounds in computer science or hardware, teachers such as Stephanie (T1), Mark (T3), and John (T4) initially expressed uncertainty about their familiarity with ME concepts. Through hands-on activities with Micro: bits, sensors, copper tape, and logic-based lessons, teachers' responses increasingly reflected an applied understanding of the content. By the end of the workshop, four of the five teachers (all teacher partners) indicated an applied understanding of the content knowledge. They referenced specific tools, lesson components, and troubleshooting strategies. Joseph (T2), who entered with greater initial knowledge (i.e., having implemented the curriculum before and is a co-author of the unit), further developed a comprehensive understanding through engagement with more advanced tasks such as circuit debugging, copper tape, and conductive thread activities. Prior enactment positioned him for deeper participation in the CoP and engagement with more advanced tasks [1]. Teaching functioned as a mechanism for professional learning, allowing iteration of content understanding through practice [37]. This point is consistent with CoP research where these communities support authentic, practice-focused activities and increase content knowledge and self-efficacy [38].

These findings are consistent with prior research on effective PD, which indicates that content-focused, active-learning PD experiences are crucial for building an applied understanding of the content [39]. Teachers worked directly with the tools and curriculum they would be expected to teach, which supports meaningful learning of content, rather than passive learning of electronics.

Self-Efficacy Development During Fall 2025 Semester

During the fall 2025 period, changes in instructional self-efficacy reflected differences in teachers' participation in the fall PD sessions and whether they implemented them in their classrooms. Despite these PD activities being required, three teachers contributed at different points during data collection. Joseph (T2), the only teacher who implemented the full ME curriculum, maintained high instructional self-efficacy throughout the semester and continued to express confidence in teaching, adapting, and supporting students during the implementation period. Jessica (T5), who participated in both fall PD sessions asynchronously but did not implement the unit, showed a decrease in self-efficacy by the end of the fall semester. This may be attributed to the lack of synchronous peer interactions and the logistical challenges during the fall semester, including a family emergency. John (T4), who had delayed participation in the second fall PD session, maintained high instructional self-efficacy; however, his responses did not indicate further growth beyond the level he achieved during the summer workshop. Stephanie (T1) and Mark (T3), who left classroom teaching during or shortly after the summer workshop, did not provide fall data, limiting their observed trajectories to only the summer workshop.

These patterns indicate that continued participation in synchronous peer interactions and implementation assisted in maintaining instructional self-efficacy. This finding aligns with CoP literature, which discusses that learning and professional identities are sustained through ongoing participation in shared practice [1], [6]. Research on professional learning also suggests that asynchronous participation can support teachers but may not fully replace the benefits of in-person collaboration for sustaining confidence and engagement [40], [41].

Content Knowledge Development During Fall 2025 Semester

Content Knowledge during the fall followed a similar pattern. Joseph (T2), who implemented the curriculum, continued to demonstrate a comprehensive and applied understanding of ME as he supported students and refined instructional materials. Jessica (T5), who did not implement but attended both fall PD sessions asynchronously, maintained an applied level of content knowledge without further growth. John (T4), who had a delayed response for the second PD activity, also remained at an applied level due to his hesitation about implementing breadboards during his future implementation. Stephanie (T1) and Mark (T3), who left teaching, could not have their content knowledge assessed beyond their final participation. Overall, these findings suggest that the summer workshop established a foundation of ME content knowledge, but additional growth was closely tied to opportunities for continued engagement and implementation of the unit.

Limitations

This study had several limitations, including a small sample of five teachers from a single ME PD program. This fact may limit the extent to which the findings can be generalized to other populations. Participation during the fall semester also varied among teachers: only one teacher implemented the full curriculum, with two others planning to implement in spring, two teachers left the classroom, one missed the second fall PD session, and one participated asynchronously in the first PD session due to a family emergency. These variations limited the ability to compare teachers' longitudinal trajectories. Since only one teacher implemented the unit thus far, the fall phase of the study mainly reflects teachers' continued engagement and perceived readiness rather than classroom implementation. In addition, the qualitative data were coded using binary indicators and then summarized using a four-level scale. This procedure helped track change over time but may not capture all variations in teachers' responses. The study also relies on teachers' self-reporting surveys and reflections rather than observations. One participant (T2) was involved in curriculum design and co-facilitation parts of the summer workshop, which may have influenced both his responses and group collaboration. Finally, the lead author of this paper had prior professional relationships with two of the participating teachers (T2 and T4); despite the use of interrater reliability procedures, this may have influenced the interpretation of their responses.

Conclusions & Future Work

Overall, this study examined how participation in a summer PD workshop influenced teachers' self-efficacy and content knowledge for implementing collaborative ME lessons. Across all five cases, teachers exhibited increased understanding of ME by the end of the summer workshop. Teachers progressed from general teaching confidence and initial uncertainty about ME topics to a sense of preparedness to teach the unit. Most teachers reported high instructional self-efficacy and applied content knowledge after engaging in hands-on activities and collaborative lesson design.

The fall period highlighted the importance of sustained engagement. The teacher who implemented maintained high self-efficacy and content knowledge, whereas the other teachers who were unable to implement or participate in person showed a decline or maintained confidence. These findings suggest that while the summer PD can effectively prepare teachers to teach ME, opportunities for peer interaction and classroom enactment are crucial for sustaining readiness.

This study focused on instructional self-efficacy and content knowledge; however, the qualitative dataset also includes additional coded themes related to identities, collaboration, instructional decision-making, and anticipated challenges. There were also quantitative datasets from the TSES that were collected and analyzed but not used to answer the research questions. These themes were beyond the scope of this current analysis but provided further insight into teachers' experiences as they engaged with ME content. Future work will examine these themes to better comprehend how teachers navigate implementation and adapt instruction within collaborative CoP contents.

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Appendix:

Appendix A: Summer Workshop Schedule

Day 1 (Tuesday)	Day 2 (Wednesday)	Day 3 (Thursday)
9:00 – 9:45 am Welcome, introductions, & week goals **9:45 – 10:45 am** You and ME You, ME, & Micro: Bit Name Tag Activity **10:45 – 11:00 am** Break & Pre-Survey **11:00 – 11:30 am** Inside your chip box & Curriculum box	**9:00 – 9:15 am** Research forms **9:15 – 9:45 am** Exploring ME careers - *subgroups* **9:45 – 10:00 am** Break **10:00 – 11:30 am** Time with your unit	**9:00 – 10:00 am** ME activity (Copper tape, garment sewing, Micro: bit lesson) **10:00 – 10:45 am** Tour of maker space **10:45 – 11:30 am** Time with your unit
11:30 – 12:00 pm Lunch	**11:30 – 12:00 pm Lunch**	**11:30 – 12:00 pm Lunch**
12:00 – 2:00 pm Intro to Curriculum *Guardians of the GRID* **2:00 – 2:15 pm** Break **2:30 – 3:45 pm** 3D printers, engineering design, client letters, & evidence-based reasoning **3:45 – 4:00 pm** Reflection	**12:00 – 3:15 pm** Time with your unit **3:15 – 3:30 pm** Reflection	**12:00 – 2:45 pm** Time with your unit **2:45 – 3:00 pm** Break **3:00 – 3:30 pm** Research, program requirements, school year work, Q&A, reflection and post-survey