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To cite this article:

Chang, T. (2025). Tech level-ups: Technology-based micro-credential program as a novel approach to K-12 professional development. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 13*(6), 1662-1679. https://doi.org/10.46328/ijemst.5906

International Journal of Education in Mathematics, Science and Technology

2025, Vol. 13, No. 6, 1662-1679 https://doi.org/10.46328/ijemst.5906

Tech Level-Ups: Technology-Based Micro-Credential Program as a Novel Approach to K-12 Professional Development

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Article Info

Article History

Received:
17 June 2025
Accepted:
5 October 2025

Keywords

Professional development
Micro-credential
K-12 education
Educational technology

Abstract

While professional development (PD) is an important part of teachers' professional growth, current PD formats are often perceived as irrelevant or too brief to significantly impact teaching practices. This mixed-methods action-research study evaluated a four-session, beginner-level fabrication-technology micro-credential (MC) program delivered to 102 distinct teachers across four cohorts. Descriptive statistics were utilized to summarize teacher demographics and self-reported comfort with fabrication technologies. Kruskal–Wallis tests were applied to compare post-session ratings of pacing, relevance, facilitator quality, and overall satisfaction across cohorts. Open-ended comments were thematically coded to capture perceived utility and classroom transfer. Participants included teachers from elementary (41.9%), middle (27.5%), and high school (20.6%) grades, with the remainder teaching multiple grades. The median comfort level with fabrication tools increased from "beginner" to "intermediate" over the sessions, while satisfaction levels remained consistently high. Differences in overall satisfaction among the cohorts were not statistically significant, $H = 3.29$, $p = .35$. Qualitative themes emphasized the importance of hands-on training, iterative practice windows between meetings, and facilitator feedback loops. The findings support the MC design principles of self-direction, job embedding, and competency-based assessment as effective solutions to common PD challenges. Implications include actionable steps for other MC programs and districts to support teachers.

Introduction

One of the key mandates of K-12 education is to prepare today's students to lead tomorrow's world. With new technologies emerging at an accelerated pace, teachers must also develop in practice and knowledge to support student achievements. Professional development (PD) courses are ubiquitous in the teaching profession to keep teachers up to date. Many existing literatures support the benefits of PD courses for both teachers and students. However, lack of oversights and inconsistencies between curricula often result in teacher dissatisfaction and minimal professional growth. Drawing on a combination of literature review and action research, I explore how micro-credential programs, particularly those focused on emerging educational technologies, can provide more targeted, flexible, and practice-oriented pathways for teacher growth. As both researcher and program facilitator, I was able to observe firsthand how teacher participants engaged with the credentialing process and how it influenced their professional practice. The goal of this paper is to lay the groundwork for program developers and educational institutions to explore the possibilities of starting their own MC programs.

Overview on Teacher Professional Development (PD) Programs

Professional development (PD) programs are defined as activities "that develop an individual's skills, knowledge, expertise, and other characteristics as a teacher" (OECD, 2009). These courses are distinct from the coursework taken by aspiring teachers to complete their credentialing requirements. PD programs are additional learning opportunities offered to in-service teachers. Depending on the subject area, purpose, and intended audience, these activities vary greatly in terms of modality, focus, setting, length, and degrees of participation.

A beginning teacher may participate in professional development activities where they work with a mentor or coach for individualized support (Kraft et al., 2018). Teachers within a school site or department may engage in professional learning communities (PLC) that are targeted to specific student needs, visions, or district directives (Vescio & Adams, 2008) or conduct lesson studies to engage in a cycle of inquiry on specific practices, strategies, or curricula (Lewis et al., 2009). While many of these programs are delivered through in-person workshops (Garet et al., 2001) to maximize collaboration, online or hybrid options offer participants the flexibility to engage from anywhere (Dede et al., 2009).

The Importance of Continuing Professional Growth

Teacher participation in PD is driven by a combination of extrinsic motivators (e.g. monetary or salary advancement) and intrinsic motivators (e.g. personal interests or curiosities). PD courses are meant for continuing professional growth of teachers in terms of practice and knowledge (OECD, 2009). The practice of continuing professional education (CE) is hardly unique to the teaching professions. Indeed, health professionals such as physicians, pharmacists, and nurses are required to participate in CE to maintain their licensure. These CE courses are designed to inform health professionals of most up-to-date practices based on research to improve patient outcomes. Almost all CE courses are standardized and accredited by national bodies and are often followed by some form of standardized performance evaluation to validate the competency of the participants (Moore et al., 2009). The purpose of CE is to ensure healthcare professionals are up to date with current available treatment options and procedures, so their patients receive the best possible care.

Similarly, PD courses provide educators with a way to continue improving their crafts. Different cohorts of students have different strengths and needs that are heavily influenced by their social environments. What were best practices few years ago may no longer be effective for today's youth. PD courses ensure teachers are equipped with the relevant strategies and practices to meet the ever-changing needs of students over time (Darling-Hammond & McLaughlin, 1995). Teachers also benefit from PD courses that are content-oriented (e.g. focus on knowledge of the subject area). A content-focused PD features subject matter knowledge that the teachers should know, both procedurally and conceptually, to minimize attrition due to time lapsed and to advance the subject matter competency of teacher participants (Garet et al., 2001). In addition, PD courses contribute to teacher's own self-efficacy and self-actualization. Darling-Hammond et al. (2009) observed that teachers are more likely to remain in the profession if they see growth in their own practices and felt their work is meaningful to them.

PD and Student Learning Outcomes

The current literature indicates that teachers participating in quality PD courses show improvements pedagogically, intellectually, and personally (Darling-Hammond et al., 2009; Darling-Hammond & McLaughlin, 1995; Garet et al., 2001). These professional growths have direct impacts on student learning outcomes across content areas. Meta-analysis on math-specific PD programs (Blank & de las Alas, 2009) and general science, technology, engineering, and math (STEM) focused PD programs (Lynch et al., 2019) both demonstrated positive impact on student learning. Teachers participating in PD programs that integrate English language development (ELD) with subject-specific strategies are generally more prepared to support ELD student achievements (Heller, 2012). If teachers within a PLC are committed to ongoing PD cycles, student achievement rates in English Language Arts (ELA) and math increase significantly across multiple grade levels (Solution Tree, 2024). While the benefits of PD are well-documented, challenges persist regarding the consistency and quality of courses across context.

Challenges in PD Courses

The absence of an accreditation-style framework for evaluating professional development (PD) allows virtually anyone to offer a "PD course", leaving districts without shared benchmarks for quality. Comparative research shows large disparities in instructional rigor across providers (Hill et al., 2013) and even district-run programs frequently lack the specificity, coherence, and sustained duration required to shift classroom practice (Desimone, 2009). At the same time, third-party vendors of PD programs are rapidly expanding their market share in what might be termed *PD-as-a-service*, a model in which districts and schools subscribe to proprietary professional development offerings rather than developing them internally or jointly with other research-based educational institutions. This mirrors the tech industry's shift toward "*as-a-Service*" (*aaS*) models, such as *Software-as-a-Service* (*SaaS*), where users license access to a product or platform instead of purchasing it outright. In both cases, the arrangement often "locks in" the user to a particular service in exchange for continued updates and support. In education, the *PD-as-a-service* model can incentivize schools and districts to remain tethered to a specific vendor through proprietary materials, programmatic structures, and delivery formats (which may be incompatible with other strategies or pedagogical frameworks). This model has proven to be lucrative, with U.S. school districts collectively spending about $18 billion annually, amounting to 2 to 4 percent of total budgets in many large urban districts, on external consultants and vendor-led workshops (Boston Consulting Group, 2014; Education Resource Strategies, 2005).

Despite the large price tag, only 29% of teachers describe their PD as highly satisfying, and many characterize vendor sessions as "irrelevant" or "thinly veiled sales pitches" (Boston Consulting Group, 2014). The problem is most visible in top-down *district initiatives* for new curricula or technologies, where workshops highlight product features but omit subject-specific pedagogy. In a national survey, nearly 50% of teachers said PD linked to purchased curricula left them unprepared to use the materials effectively (EdReports, 2023). This mismatch between supply and need lowers teacher engagement and creates skepticism about the promise of professional growth, making educators less willing to invest time and effort in future PD offerings (TNTP, 2015). To address this issue, there needs to be a set of standards, or traits, that are shared among effective PD courses.

Making it Stick: Characteristics of Effective PD Courses

Within the context of this paper, effectiveness is defined as what teachers *perceived* to be both *useful* and *useable* at the time of participation. This definition allows the study to focus on the design and delivery of PD courses without conflating it with the issue of implementation fidelity, which is often constrained by external factors such as school budgets, leadership priorities, or logistical limitations.

What Do Effective PD Courses Have in Common?

To calibrate our initial definition of *perceived effectiveness*, Garet et al. (2001) identified five core components of effective professional development (see Table 1), which provide a structural benchmark for PD design and evaluation.

Table 1. Five Components of Effective PD

Content Focus	Emphasis on subject matter content and how students engage with that content.
Active Learning	Opportunities for hands-on tasks, modeling, and discussion among participants.
Coherence	Alignment with standards, curricula, and teacher or school goals.
Duration	Sustained across multiple sessions to support deep learning.
Collective Participation	Engagement of teacher cohorts who share similar roles, contexts, or grade levels.

Desimone (2009) further built on the five components in Table 1 by connecting high-quality PD and meaningful changes in teacher knowledge and beliefs, which then ultimately improve student outcomes through changes in practice. According to this model, PD is most effective when it is not only well-structured but also provides experiential learning opportunities that mirror what students might encounter. Teachers who participate in content-specific programs with ample time for hands-on practice are more likely to develop the confidence and competence to implement new strategies. In this sense, both the structural integrity and the immersive, participant-centered nature of PD are key to making learning "stick."

Micro-Credentials as a Targeted PD Solution

Micro-credential (MC) programs are a specialized subset of professional development (PD) programs typically focused on a particular skillset or subject matter. Upon completion, teachers will typically receive a *micro-credential* (different from a teaching credential) that certifies the competency the participant on said skillset along with a digital badge that can be validated. MC programs addressed many shortcomings of traditional PD by focusing on four key design elements: *self-directed*, *job-embedded*, *competency-based*, and *research-based* (Acree, 2016). Each of the elements works in tandem to support teacher professional growth.

Self-directed Structure for Agency and Flexibility

Unlike traditional PD that are facilitator-led or paced, MC allows participants to work and develop their skills at their own pace throughout the entire program, over the span of multiple sessions. On average, most PD in the United States lasted three days or shorter (Schwartz, 2023). While this might offer teachers maximum convenience, it is very likely that the teachers do not have ample time to process, apply, evaluate, and improve within that time span. Darling-Hammond and Gardner (2017) noted that most effective PD models often have meeting patterns that involves multiple meeting days that are spaced out. The intentional gaps between sessions serves as trial periods where teachers can practice their learning in ways they believe is most beneficial for their students as well as collect data for refinement during the next session. In addition, MC addresses the problem of specificity (or lack thereof) in traditional PD by offering courses that focus on specific skills or skillsets. This allows professional learning to be tailored to specific teacher needs or goals rather than a broad survey of strategies. This gives educators a way to develop and demonstrate mastery based on their own needs and interests within their own teaching context ("Micro-Credentials," n.d.-a).

Job-embedded Approach Supports Immediate Applications

One key challenges of traditional PD is the lack of relevance (Schwartz, 2023). Within the context of this paper, I have identified two root causes from literature: *content mismatch* and *application uncertainty*. *Content mismatch* are instances where the delivered content is not within the subject matter or age/grade band of the participants (e.g., a math teacher at a writer's workshop training). *Application uncertainty* occurs when the participants acknowledge the usefulness of the content but are uncertain about *how* to apply the content within their teaching context (e.g., novel approach to teach rhetorical analysis for new teachers). Borko (2004) found that effective PD needs to be directly relevant to classroom practices that aligns with the teaching context of the participants and supports the development of skills and strategies that teachers can immediately implement and practice. MC programs are inherently job-embedded because they are skill or subject matter-specific. Teachers participate in MC programs that are aligned specifically for certain job-related (in this case, *teaching*) needs that they can develop over several sessions. Each meeting provides opportunities for teachers to learn new skills and refine learned skills while time between meetings serve as sandbox for teachers to apply their learning and reflect on results (Acree, 2016). This structure makes MC program highly relevant and applicable to participants and thus supports long-term professional growth.

Competency-based Assessment Validates Learning

If the goal of PD participation is teacher growth in practice and knowledge, there needs to be some form of assessment to validate that growth. Majority of traditional PD programs are offered over the span of three days or less, which is too short to be effective (Schwartz, 2023). In addition, the facilitator-centered workshop model does not give participants the opportunity to gain hands-on experience to practice nor does it provide meaningful checks for understanding. This makes traditional, workshop-based PD more difficult to validate because of the lack of assessment criteria and the credit-hour-based nature of these programs (Joshi et al., 2020). Unless the teacher has some form of syllabus or detailed description of the course, there is virtually no means to determine whether certificate of completion demonstrates *competency* or *attendance*.

On the contrary, MC programs are skill-focused and competency-based. This means teacher participants will only earn their certification after completing some form of performance task at a satisfactory level (Acree, 2016). Over the course of the entire MC program, participants are required to collect evidence demonstrating that they not only know the content, but also know how to apply it within their own classroom settings (*Micro-Credentials*, n.d.-b). The time in between sessions gives teachers opportunity to practice, reflect, revise, and improve on their skills. Because the teachers are practicing within their real teaching context, they are more likely to internalize the skills and retain it over longer periods of time (Acree, 2016; "Rethinking Learning Through Educator Micro-Credentials," 2024).

Research-based Design and Validation, Not Just Content

Both traditional PD and MC program contents are grounded in current educational research and pedagogical framework. However, micro-credentials further apply the research and framework into the design and validation of the course as well. This means not only are the contents research-based, so is the way the course is delivered and assessed. For example, both Desimone (2009) and Darling-Hammond et al. (2017) identified the importance of active learning, sustained engagement, collaboration, and coherence in PD course to maximize teacher growth. MC embody these elements by using performance-based assessment, embedded reflection and feedback cycles, and artifact-driven evidence in tandem to support teachers in reaching mastery. In contrast, while many traditional PD offer content that is research-aligned, the method of delivery and assessment of teacher growth remain ineffective.

As demonstrated in the previous sections, there are many features of MC that directly address the major deficits of traditional PD. It is worth noting that MC programs are almost always skill-based in design. There are subject matters and topics that MC would be ineffective when compared to traditional format. Thus, this article does not seek to completely replace traditional PD with MC but rather to showcase how MC can be used in one subject area: *technology and educational innovation.* The following sections will be focused on a specific micro-credential program offered by California State University, Dominguez Hills in which the author of this paper developed and facilitated.

Study Context and Program Origin

In the summer preceding the 2021–2022 school year, I was invited by the Center for Innovation in STEM Education (CISE) at California State University, Dominguez Hills to develop and facilitate a beginner-level micro-credential (MC) program on fabrication technologies. The program, titled Fabrication Technology Certification: Beginner Level, was created in partnership with nearby public-school districts and aimed to introduce K–12 teachers to hands-on digital fabrication tools such as 3D printers and vinyl cutters and their applications in classroom instruction. Most participants had little to no prior experience with these tools, and some expressed initial apprehension toward technology integration in general.

As both a classroom teacher and the program facilitator, I recognized the need to design a course that was not only informative, but also practical, engaging, and responsive to teacher concerns. To that end, I intentionally aligned the program structure to key elements of effective PD and micro-credential design: self-directed learning, job-embedded activities, and competency-based assessment (Acree, 2016). This also created a valuable opportunity to investigate how these elements, when implemented in a real-world setting, shaped teacher participation, confidence, and professional growth.

Methods

This study is grounded in a practitioner-researcher methodology, drawing from action research and design-based implementation research (DBIR) traditions. As both the facilitator and designer of the micro-credential (MC) program, I occupied a dual role that allowed for iterative cycles of planning, acting, observing, and reflecting (Kemmis & McTaggart, 2005). This approach was particularly appropriate given the goals of the study: to explore how a real-world, technology-focused MC program could embody the principles of effective professional development (PD) and influence teacher practice. However, it is important to note that not every PD provider and facilitator were given the freedom to make in-the-moment changes to their content and delivery to meet their participants' needs.

Rather than isolating variables in a controlled environment, practitioner inquiry highlights the real-world messiness within actual educational contexts and seeks to generate actionable knowledge grounded in the lived experiences of educators (Cochran-Smith & Lytle, 2009). In this study, I was not only documenting participant responses but also adapting the program in real-time based on teacher feedback, engagement levels, and observed needs. The evolving nature of the intervention reflects a design-based stance, in which the program was both the subject and the vehicle of inquiry.

While generalizability is not the primary aim of this study, the combination of embedded inquiry and participant data offers transferable insights into how MC programs might be structured for greater teacher engagement and relevance. By approaching the study as both a developmental process and a site of reflection, I aimed to surface design principles and practitioner insights that can inform future implementation of micro-credentialing as a PD model. This article seeks to answer the following research question: *If teachers participate in a micro-credential* *focused on fabrication technologies and engineering design practices, how does it affect their perceived self-efficacy and professional growth?*

Study Participants and Data Collection

A total of 403 post-session surveys (see Table 2) were collected from four cohorts of the *Fabrication Technology Certification: Beginner Level* micro-credential (MC) program. Each cohort met over the span of four consecutive Saturdays and participants completed an exit survey at the end of each session. Following Desimone (2009) and Guskey's (2002) recommendations for repeated-measures professional-development studies, the number of surveys in each cohort was divided by the four-session structure (rounded up) to yield an estimated 102 unique participants.

Table 2. Survey Responses and Estimated Unique Participants by Cohort

Cohort	Surveys Collected	Estimated Unique Teachers
2022 Winter	64	16
2023 Spring	119	30
2023 Fall	71	18
2024 Spring	149	38
Total	**403**	**102**

All surveys were de-identified prior to analysis; names, e-mail addresses, and any free-text fields that could reveal identity were removed by program staff. Demographic variables (gender, ethnicity, grade level, and subject taught) were drawn from each educator's first submission within a cohort to minimize attrition bias while preserving one record of demographic information per teacher. Missing demographic responses were coded as *Unknown* rather than deleted, maintaining the full analytic. Although the dataset may contain duplicated entries, they have minimal impact to the overall quality of the dataset since the responses were analyzed as aggregate and tracked within each cohort.

Measures

To quantitatively measure participants' self-efficacy and perceived quality of the professional development course, this study examined exit survey items that correspond to Technology-Integration Self-Efficacy (TISE) and Professional Development Quality (PDQ)

Technology-Integration Self-Efficacy (TISE)

Seven Likert items (1 = Very Uncomfortable, 4 = Very Comfortable) captured teachers' confidence in operating and teaching foundational fabrication tools (e.g., 3-D printer, vinyl cutter) plus a transfer item ("I can readily apply the PD content in my classroom"). Items were averaged to form a composite (higher = greater self-efficacy).

Professional Development Quality (PDQ)

Six exit-survey items rated content relevance, pacing, facilitator knowledge, engagement, and applicability on a 1–5 agreement scale (1 = Strongly Disagree, 5 = Strongly Agree). Items were averaged.

Quantitative Analysis

Because the exit survey underwent several revisions to improve readability and flow, the headers do not always match between cohorts. Raw CSV exports were screened for header artifacts and recorded so that Likert responses mapped to consecutive integers (1-4 or 1-5), with higher scores indicating more positive perceptions. TISE and PDQ items were validated for internal consistency using Cronbach's α. The item sets were then averaged to create composite scores. Cases missing all items within a composite were list-wise deleted for that composite; otherwise, item means were calculated with available items. Medians and interquartile ranges (IQRs) were calculated for each composite score by cohort and by session.

Given that TISE and PDQ are ordinal and non-normal, non-parametric tests were used for inferential testing. Kruskal-Wallis tests were used to determine cohort-level differences in TISE and PDQ with results reported as eta-squared (η^2). A Wilcoxon signed-rank test was used to assess pre- versus post-session change in technology-use comfortability for records with matched responses. This study used Cliff's delta (δ) as effect-size metric.

All quantitative data cleaning, descriptive statistics, and inferential tests were performed in Python 3.11 (Python Software Foundation, 2024). Data wrangling relied on pandas 2.2 (pandas Development Team, 2024), while numerical operations used NumPy 1.26 (Harris et al., 2020). Non-parametric tests (Wilcoxon signed-rank; Kruskal–Wallis) were executed with SciPy 1.13 (Virtanen et al., 2020). Figures were generated in Matplotlib 3.9 (Hunter, 2007). Qualitative coding and retrieval were conducted in NVivo 14 (QSR International Pty Ltd., 2024). Statistical significance was set at $p < .05$ (two-tailed).

Qualitative Coding

Open-ended comments were coded inductively in Nvivo 14. An initial descriptive coding cycle was followed by thematic consolidation based on Guskey's levels 1 (Reaction) and 4 (Use of new knowledge). In addition, the study conducted an intra-rater reliability check by re-coding 20% of comments after a two-week interval with 96% agreement.

Results

The results in this section were based on post-session surveys from four distinct cohorts of teachers. The total number of survey entries analyzed was 403 and the estimated number of unique participants was 102 people. The demographic breakdown of the participants is shown in Table 3. Blank entries were treated as "unknown" for the purpose of this study.

Table 3. Demographic Information of Study Participants

Gender	**Count**	**Percentage**
Female	74	72.5%
Male	19	18.6%
Unknown	7	6.9%
Prefer To Not Say	2	2.0%
Ethnicity	**Count**	**Percentage**
Hispanic/Latinx	52	51.0%
Black / African American	18	17.6%
White	15	14.7%
Asian / Pacific Islander / Native Hawaiian	11	10.8%
Multiracial / Other	6	5.9%

The teaching context of participants was equally diverse, as shown in Table 4. In terms of grade levels, majority of the participants were elementary school teachers (TK-5th) followed by middle school teachers. As a result, a large share of the participants are multiple subject teachers (in self-contained elementary classrooms).

Table 4. Teaching Context of Study Participants

Grade Band	**Count**	**Percentage**
Elementary (K-5)	42	42%
Middle (6-8)	32	31%
High (9-12)	26	25%
Multiple grade bands	2	2%
Subject Area	**Count**	**Percentage**
Multiple Subjects (self-contained)	141	45.6 %
Mathematics	48	15.5 %
Science	47	15.2 %
Social Studies / History	28	9.1 %
Non-classroom roles	23	7.4 %
English / Language Arts	22	7.1 %

For participants teaching more than one subject area at a middle or high school level, each identified subject area adds to the overall count for that subject area. For example, a teacher who teaches both a science and a mathematics class at a middle school would contribute one count to both science and mathematics. Therefore, the count for subject areas is significantly larger than the total participants in the study.

Quantitative Results

The internal consistency for Technology-Integration Self-Efficacy (TISE) and Professional Development Quality

(PDQ) was validated using Cronbach's α with calculated values of $\alpha = 0.86$ and $\alpha = 0.79$, respectively. Both indices met the threshold of $\alpha \geq 0.70$ for reliability (Nunnally & Bernstein, 1994).

Technology-Integration Self-Efficacy (TISE)

The median composite score for 2022 Winter, 2023 Fall, and 2023 Spring cohorts held steady at 3.00 while 2024 Spring cohort had a score of 2.77 (see Table 5). A Kruskal-Wallis test was nonsignificant with reported values of $H(3) = 4.77$, $\rho = .189$, $\eta^2 = .005$.

Table 5. Median (IQR) Technology-Integration Self-Efficacy Scores by Cohort

Cohort	***n*** [a]	**Median**	**IQR**
Winter 2022	29	3.00	1.12
Fall 2023	55	3.00	1.25
Spring 2023	35	3.00	1.11
Spring 2024	76	2.77	1.02

[a] *n* represents the number of session-level survey responses with a non-missing TISE score; individual teachers could contribute multiple responses across sessions.

Although participant responses could not be linked longitudinally across sessions due to data anonymization, session-level medians increased from 2.15 in Session 1 to 3.58 in Session 4 (see Figure 1) which demonstrated practical professional growth over the course of four sessions despite fluctuations between sessions.

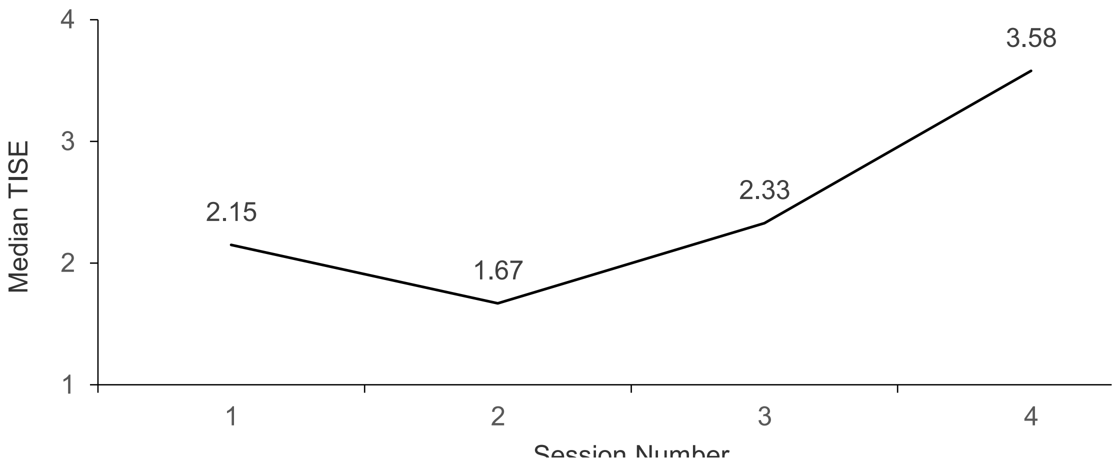

Figure 1. Median TISE Across Sessions of All Cohorts

Note. TISE score of 1 represents "*very uncomfortable*" while 4 represents "*very comfortable*"

In terms of participant comfortability in operating the 3D printers, median comfort level rose from 2 (uncomfortable) to 3 (comfortable). A Wilcoxon Signed-rank test was significant with a medium-large effect (see Table 6).

Table 6. Pre- to Post-session Change in Comfort [a] Operating a 3D Printer (N=108) [b]

Metrics	Value
Median (Pre)	2.00
Median (Post)	3.00
Wilcoxon signed-rank W [c]	120.00
p value	< .001
Cliff's δ [d]	0.43

[a] Comfort rating was on a scale from 1 (*Very Uncomfortable*) to 4 (*Very Comfortable*).

[b] *N* reflects matched pre/post survey pairs; teachers who attended multiple sessions contributed multiple pairs.

[c] Positive *W* indicates higher post-session ranks.

[d] Cliff's δ values of .11, .28, and .43 correspond to small, medium, and large effects, respectively (Romano et al., 2006)

Professional Development Quality (PDQ)

Exit-survey data from the two cohorts 2022 Winter and 2023 Spring) that completed the items related to Professional Development Quality (PDQ) showed uniformly high ratings (Median = 5.00). A Kruskal-Wallis test confirmed no cohort difference, $H(1) = 0.07$, $p = .80$. The quantitative patterns demonstrated in this section can be further illuminated by the following qualitative analysis.

Qualitative Results

A total of 231 open-ended comments ($n = 231$) were retained after removing comments that were too general *("it's great!")* or blank. Coding followed Saldaña's (2021) two-cycle protocol: inductive–deductive coding process yielded 18 initial codes, which were collapsed into four analytic themes aligned with Guskey's (2002) professional-development evaluation levels.

Theme 1: Immediate Relevance and Engagement (Guskey Level 1)

Study participants consistently provided positive feedback regarding session design, citing hands-on tasks and facilitator expertise. 82% of comments in this theme used words such as "engaging," "interactive,", or "fun." A participant stated, *"Class was super engaging and fun!! At first, I felt a bit out of my depth, but I ended up liking it."* (Fall 2023, Session 1)

Theme 2: Growth in Technical Confidence (Guskey Level 2)

Participants' comments reflected a shift from apprehension to confidence in operating technologies, demonstrating quantitative rise in TISE. A participant reflected, " *"I feel more confident."* (Spring 2024, Session 1)

Theme 3: Classroom Transfer and Integration Plans (Guskey Level 3)

Nearly half the teachers (47%) outlined specific lesson ideas (e.g., laser-cut cell models, 3D-printed historical artifacts), showing intent to integrate fabrication into existing curricula. In the final reflection, a participant wrote, "*I'm taking away a feeling of excitement. I want to implement fabrication into my lessons.*" (2022 Winter, S4).

Theme 4: Structural Barriers and Time Constraints (Guskey Level 4)

Despite enthusiasm, teachers cited numerous hurdles that may prevent them from implementing the technology long-term. Most cited barriers were limited prep time, access scheduling, and supply costs. Participants also felt the pacing in some parts of the program were off. One participant provided the following feedback, "*Pace was slow—a lot of downtime but not enough time to plan and understand how to design egg-drop projects*." (2024 Spring, S1).

Joint Display of Mixed-Methods Findings

Table 8 juxtaposes quantitative outcomes with representative qualitative quotes, illustrating convergence (e.g., rising self-efficacy paired with "confidence" statements) and divergence (e.g., uniformly high PDQ ratings vs. time-constraint concerns).

Table 8. Mixed-Methods Findings

Quantitative Indicator	**Qualitative Theme**	**Illustrative quote (cohort, session)**
TISE session median rose from 2.15 to 3.58	Technical confidence (Theme 2)	I realized that I was capable of working with technology that seemed so complicated and di… (2024 Spring, S4)
High PDQ median = 5.00 (ceiling)	Immediate relevance & engagement (Theme 1)	Class was super engaging and fun!! At first I felt a little uneasy as technology is out of… (2023 Fall, S1)
47% of comments outlined classroom transfer plans	Classroom transfer plans (Theme 3)	I'm taking away a feeling of excitement. I want to implement fabrication into my lessons.... (2022 Winter, S4)
No cohort difference, but 2024 Spring median dipped to 2.77	Structural barriers & time constraints (Theme 4)	Pace was slow. A lot of downtime but not enough time to plan and understand how to design … (2024 Spring, S1)

The mixed method approach utilizing quantitative and qualitative analysis illuminated areas of convergence and divergence. This paper will seek to interpret the results in the following section.

Discussion

At the start of this article, we posed the following question: *If teachers participate in a micro-credential focused on fabrication technologies and engineering design practices, how does it affect their perceived self-efficacy and professional growth?* Our data, both quantitative and qualitative, suggested a (nuanced) positive answer. Quantitatively, teachers exhibited a medium practical gain in 3D printing skills (Cliff's $\delta = 0.43$) and a steady rise in the composite TISE median from Session 1 (2.15) to Session 4 (3.58). Qualitatively, teachers themselves described this shift as "*feeling more confident"* and "*no longer afraid of breaking the machine*" (2024 Spring, S1), illustrating alignment between numerical trends and lived experience (Theme 2).

Despite uniformly high PDQ medians (5.00), open-ended comments revealed structural barriers such as pacing, time constraints, and equipment and budget limitations (Theme 4). In support of previous studies, this divergence echoes Desimone's (2009) caution that satisfaction scores often mask implementation hurdles. The observed growth in self-efficacy supports Bandura's (1997) theory that mastery experiences gained from hands-on tool operation are the most potent source of efficacy beliefs. The program's design also reflects Guskey's (2002) Level 1 and Level 2 outcomes: positive participant reactions and evidence of learning. While there are signs of classroom transfer (Level 3), follow-up classroom observations would be needed to confirm sustained practice change. The lower TISE median in 2024 Spring (2.77) did not reach statistical significance but nonetheless raised interesting questions regarding the cause. One plausible explanation is contextual overload since the last two sessions in the spring coincide with state testing and final grades windows. However, more cohort data is needed to support this explanation.

Limitations

The data set deliberately strips names and e-mails after each Saturday submission to protect participant privacy. While this safeguards confidentiality, it prevents linking a teacher's Session 1 survey to their Session 4 survey. As a result, longitudinal change is inferred only at the group level (median shifts) rather than by modeling within-teacher trajectories. Any gains we report could therefore be influenced by changes in the composition of attendees across sessions.

With regards to TISE and PDQ items, more than 85 % of respondents selected the top scale point (Strongly Agree) on the six PDQ items, producing a median of 5.00 with an IQR < 0.20. Such restricted variance masks nuanced differences between cohorts or sessions and inflates the likelihood of Type II error. Future iterations should consider qualitative follow-ups to capture gradient opinions. In addition, both TISE and PDQ rely on teachers' self-perceptions and are prone to bias. Prior research shows self-efficacy ratings can overestimate actual classroom practice, especially immediately following a hands-on workshop. Classroom observations would triangulate whether reported confidence translates into sustained instructional change. The voluntary nature of this PD program means participants already has an interest in technology integrations and contributed to the overall growth in TISE and PDQ. In addition, attendance varied across the four Saturdays, attenuating or inflating apparent growth trends. Randomized cohort assignment or mandatory PD credits would increase generalizability.

Finally, we used Cronbach's α (.86 for TISE; .74 for PDQ) because it is widely reported and easily interpreted. Exploratory factor analysis suggested a single-factor solution with roughly uniform loadings. Results should therefore be interpreted as a conservative estimate of internal consistency.

Implications

The results of this study yielded several actionable implications. Many comments indicated teachers need structured blocks to design lessons, not just tool demos. Similarly, many participants felt there needs to be a foundational tool training first, followed by content-specific integration modules to scaffold confidence and classroom transfer. With many teachers citing budget and resources as their top barrier to adoption, districts should consider additional funding lines for teachers and schools that wish to begin incorporating technologies into their curriculum. Finally, to fully realize Guskey's Level 4 and 5 of professional growth, follow-up virtual office hours or peer mentoring can reinforce skill retention and sustained practices.

Conclusion

This study demonstrated that a four-session micro-credential focused on fabrication technology and engineering design can rapidly elevate teachers' self-efficacy but also surfaced critical constraints that must be addressed for teachers to implement fully in their classrooms. Quantitatively, teachers showed a medium practical gain in comfort operating a 3D printer and a steady increase in the TISE composite from Session 1 to Session 4. Qualitatively, participants articulated newfound confidence, specific lesson-integration plans, and persistent barriers such as limited preparation time and equipment access. Together, these convergent strands provide compelling evidence that brief, hands-on PD that is aligned to job-embedded goals can move teachers towards authentic classroom applications. Future research should consider conducting classroom observations and collecting classroom artifacts over an extended period to determine whether improved teacher self-efficacy translates into sustained instructional change and deeper learning for students.

Acknowledgements

The author would like to acknowledge the following individuals and entities for their support of this work, both materially and morally: Dr. Cecilia Duenas, Dr. Anthony Normore, Dr. Kamal Hamdan, Ms. Kimberly Martinez, Center for Innovation in STEM Education at California State University Dominguez Hills. The author would also like to acknowledge the online community of Stack Overflow and Cross Validated for their guidance on Python scripting and statistical analysis.

This material is based upon work supported by the National Science Foundation Robert Noyce Mastery Teacher Fellowship (MTF) Track (1949973). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation. The study received exempt status from the California State University, Dominguez Hills Institutional Review

Board under protocol number IRB-FY2025-101.

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