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Engineering Tomorrow's AI-Powered STEM Teachers: An NSF-Funded Innovation in K-12 Leadership Development (Work in Progress)

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Abstract

Given the rapidly evolving landscape of generative AI in STEM education, this Work-in-Progress paper describes an active 3-year NSF-funded initiative at a private university in Massachusetts that addresses the critical need and growing demand of K-12 teachers and administrators to integrate technological knowledge, pedagogical knowledge, and content knowledge of generative AI, or the GenAI-TPCK framework, to enhance teaching and learning in high school STEM classrooms. The program provides participants with the opportunity to engage in an immersive professional development (PD) experience focusing on generative AI for one summer week, followed by continued engagement over the course of the following academic year, to build their efficacy in AI-informed teaching and their students' AI-powered learning. The paper first outlines the program's six objective components: 1) AI foundations, 2) generative AI tool proficiency, 3) AI-informed lesson plan development, 4) AI-powered classroom implementation and assessment, 5) professional development (PD) model evaluation and scaling, and 6) professional learning community (PLC) leadership. Participants included 12 public high school science and engineering teachers from 7 different school districts. This first cohort formed a community of practice to support and sustain their efforts. Program evaluation was designed to provide insights for the leadership team to inform future components of the upcoming year-long program, as well as to gather participant feedback to help improve next year's summer AI institute. Teachers shared that the summer PD experience shifted their mindsets from being initially skeptical of using AI to overwhelmingly integrating AI into their classrooms. Some also shared in their AI Action Plans that they intended to take on leadership roles in their schools and districts by training colleagues and informing district policies on AI task forces, evidence of which was captured in follow up meetings and conferences. Overall, participants agreed that the summer AI PD experience was highly positive and that they felt significantly more confident and prepared to incorporate AI into their teaching. As the program is still ongoing, future work will focus on providing support and peer networking to teachers for the remainder of the 2025 – 2026 academic year and preparing the program to incorporate the next cohort beginning in summer 2026, leveraging the teachers' leadership experiences as their PLC grows.

Introduction

AI-informed pedagogy in STEM content areas, particularly in engineering, supports our national STEM educational ecosystem [1]. However, many educators lack the knowledge or expertise to effectively integrate generative AI into their teaching [2]. Koehler and Mishra introduced the original Technological Pedagogical Content Knowledge (TPCK) theoretical framework in 2005 in the context of online learning [3] and built upon Shulman's landmark paper describing Pedagogical Content Knowledge [4]. In their seminal paper, Koehler and Mishra stated that "Good teaching is not simply adding technology to the existing teaching and content domain. Rather, the introduction of technology causes the representation of new concepts and requires developing a sensitivity to the dynamic, transactional relationship between all three components suggested by the TPCK framework." [3]. More recently, educational researchers, including

Mishra, have adapted the TPCK framework to address generative AI (GenAI) as the emerging technology challenging educators today [5 - 8].

In simple terms, *content knowledge* (CK) is the subject matter that is to be taught and learned. *Pedagogical knowledge* (PK) refers to educational practices, strategies and methods of teaching and learning and includes knowledge about instruction, assessment and how students learn. *Technological knowledge* (TK) refers to modern tools such as pencils, books, blackboards and more recently computers, the Internet, digital literacy, online learning platforms, and generative AI. Technological knowledge about generative AI is the newest addition to educators' toolkits and arguably the least understood because it involves understanding their educational applications, ethical considerations, and functional limitations. Educators with advanced TK can use generative AI tools effectively and critically assess their instructional value and limitations.

In the TPCK framework, combining content knowledge and pedagogical knowledge results in the construct *pedagogical content knowledge* (PCK), which is defined as the "knowledge of pedagogy that is applicable to the teaching of specific content" [3]. For example, educators with excellent engineering pedagogical content knowledge leverage important ways of teaching engineering that are unique to the discipline, particularly the engineering design process.

Technological content knowledge (TCK) is defined as "knowledge of how a subject matter is transformed by the application of technology" [3]. Educators with strong TCK can evaluate AI-generated content critically and recognize discipline-specific uses of generative AI in a rapidly changing society.

Technological pedagogical knowledge (TPK) in the age of AI refers to pedagogical practices that leverage AI technology to reimagine teaching and learning. However, a basic understanding of AI literacy, including the benefits and limitations of generative AI are first required [6]. Educators proficient in TPK know how to use generative AI to support varied instructional strategies.

The *Technological Pedagogical Content Knowledge* (TPCK) framework postulates that effective integration of any technology requires an understanding of the complex relationship between all knowledge components, including the *conteXtual Knowledge* (XK) that circumvent it such as district AI policies and budgetary constraints (Figure 1) [6].

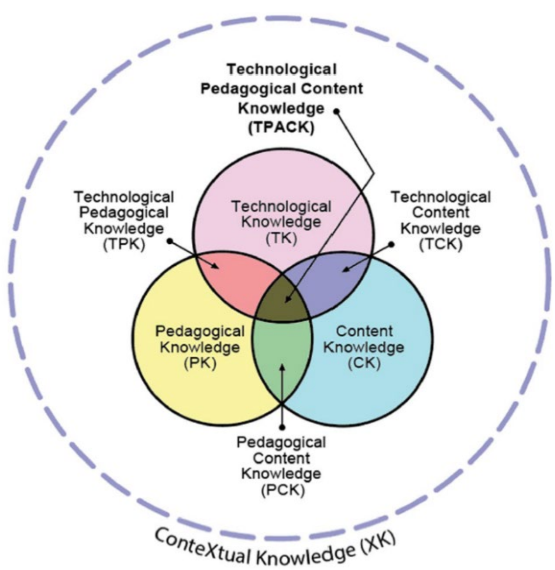
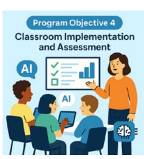


Figure 1. TPCK framework as illustrated by Mishra, et al. [6]

Therefore, in the context of our teacher community of practice, the TPCK theoretical framework serves as our foundation to support high school STEM educators, their students, and their districts. In a recent 2025 systematic review of over 73 articles about AI in education, Liu and Zhong concluded that "educators who possess TPCK demonstrate strategic competence in designing, implementing, and evaluating AI-enhanced learning experiences that simultaneously promote subject mastery, pedagogical interaction, and students' AI literacy" [2]. In addition the authors concluded that “the TPACK framework helps ensure that the integration of GenAI occurs not as an isolated intervention, but as a coherent element within a comprehensive educational strategy” [2].

Program Objectives

Objectives for the program were established in the original grant proposal and designed through the lens of the GenAI-TPCK framework.

	**Program Objective 1: AI Foundations and Historical Context** Participants will be able to explain the historical development of artificial intelligence and current generative AI technologies, demonstrating foundational knowledge necessary for informed classroom integration.
	**Program Objective 2: Generative AI Tool Proficiency** Participants will be able to effectively use generative AI tools relevant to STEM education, including prompting strategies, output evaluation, and appropriate ethical application within educational contexts.
	**Program Objective 3: AI-Informed Lesson Plan Development** Participants will be able to design, develop, and refine AI-informed lesson plans that align with [state] curriculum frameworks while incorporating generative AI tools to enhance student learning and engagement.
	**Program Objective 4: Classroom Implementation and Assessment** Participants will be able to successfully integrate AI-informed lesson plans into their STEM classrooms and assess the effectiveness of AI tools in supporting diverse learners.
	**Program Objective 5: Professional Development Model Evaluation and Scaling** Participants will be able to analyze the effectiveness of the hybrid professional development model (combining direct instruction with learning community approaches), provide feedback on program elements, and contribute to the refinement of a scalable model that can be replicated across different schools and districts.
	**Program Objective 6: Professional Learning Community Leadership** Participants will be able to share experiences, provide constructive feedback to peers, and contribute to the broader professional learning community focused on AI in education, ultimately serving as AI education leaders within their schools and districts.

Graphics for each program objective were generated using ChatGPT [9].

Participants

In the first year of the program, high school STEM teachers from partner public school districts which had provided letters of collaboration for the original grant proposal were invited to apply. Twelve teachers (7 male, 5 female) from 7 different school districts were selected as participants. Five self-identified as teaching biology, four physics, two chemistry, two engineering/robotics, two marine science and one computer science, which includes four teachers teaching more than one subject area. Other demographic data were not collected. As defined in the grant award, participants received a stipend for completing the week-long AI Summer Institute and for "callbacks" during the 2025-2026 academic year.

Summer AI Institute

In June 2025, teachers attended two virtual hour-long meetings prior to the start of the summer week which introduced Foundations of AI in education, upcoming logistics, and the AI Action Plan. The AI Action Plan was designed with resources from EdTechTeacher, AI for Education and the Learning Accelerator to include sections and reflection questions on AI classroom implementation goals, scope and focus areas, AI tools and resources, anticipated milestones, timelines, continued learning, data collection, evaluation and feedback, and long-term integration. In July 2025, teachers participated in an intensive one-week (four day) in-person summer PD session on our Boston campus. In total, the Summer AI Institute covered 30 PD hours and focused on eight content delivery goals, each designed to support the educator's development of their own AI Action Plan, which they presented on the last day.

8 content delivery goals:
1. Foundations of AI in Education
2. AI Tools for Teaching and Curriculum Development
3. AI for Student-Centered Learning
4. AI-Informed Lesson Plans
5. AI-Powered Assessment Tools and Methods
6. Interactive Collaboration and Problem-Solving with AI
7. Ethical Use of AI in Schools
8. Developing your own AI Action Plan

Community of Practice supports Leadership in Teachers' Professional Learning Communities

The program is designed to create a growing community of practice, starting in the first year. The summer AI institute is held in person for this very reason. A free web-based project management platform called Basecamp [10] was used for communications, sharing files, and posting announcements, including direct email notifications. Two follow-up meetings with the community of practice were held in Fall 2025. The first fall "callback" was a virtual hour-long meeting that served as an update from each teacher on their AI implementation progress, including one lead teacher's progress on creating a website for our project [11]. The second fall meeting was an in-person conference panel presentation at the state's science teacher conference where each teacher shared their successes and challenges using AI in the classroom. In addition, two more follow-up meetings were held in Spring 2026, including a virtual discussion of their classroom AI implementation progress and an in-person conference panel presentation at a local EdTechTeacher AI in EDU Summit.

All 12 participants in the first community of practice made considerable progress toward Program Objective #6 as school/district AI leaders themselves, either by serving on AI task forces, leading AI PD for other teachers, or by mentoring their colleagues during the academic year. This is a noteworthy outcome which demonstrates the amplified impact of the program even in the first year.

As for specific teachers of engineering, their AI Action Plans focused on helping students learn to responsibly use AI in their design projects by intentionally crafting AI prompts to research physics and engineering connections, brainstorm possible solutions, and to identify potential improvements to their designs. The robotics teachers incorporated AI into their teaching by building a custom Google NotebookLM chatbot with course-specific resources for students and by incorporating metacognition assignments into their AI literacy lessons.

Program Evaluation

Program evaluation was designed to provide insights for the project leadership team to improve future summer AI institutes and for enhancing community of practice activities during the academic year. A retrospective survey was deployed by an external evaluator at the conclusion of the 2025 summer AI institute to assess teachers' experiences during the PD.

Questions in this retrospective survey included confidence in using AI in teaching along a 5-point Likert scale, change in confidence as a result of the summer PD, ratings of the program facilitators, program content, and program logistics, and open-comment responses about participants' most rewarding and most frustrating experiences. The survey also asked participants to identify upcoming needs and anticipated impacts on their teaching. All 12 participants completed the survey for a 100% response rate. The host university's Institutional Review Board approved the external evaluator's plan to assess the program.

Evaluation Findings

Overall, the PD experience was highly positive, with 12 out of 12 (100%) participants feeling significantly more confident and prepared to incorporate AI into their teaching than they were at the start of the PD. Participants attributed this confidence to the PD, in their understanding of the various AI tools (technological knowledge), AI's value in education (technological content knowledge), and their ability to use AI for lesson planning (technological pedagogical knowledge). The average confidence rating for adapting (4.7/5.0) and using AI-ED lessons (4.5/5.0) in their classrooms was high. However, confidence was slightly lower for incorporating AI ethics (4.1), policy (3.9), and social learning (3.8) into their lessons, suggesting these are areas of ongoing concern.

The program's hands-on approach, peer collaboration, and dedicated time for exploring tools were cited as the most rewarding aspects. Participants especially valued the experience of learning from other teachers and forming a community of practice.

Finally, findings demonstrate that the experience successfully shifted mindsets. Several teachers mentioned they were initially skeptical of using AI in their classrooms due to cheating concerns but now feel confident in teaching AI's ethical use. They committed to implementing AI in their classrooms in their STEM subject areas. They expected to take on leadership roles training colleagues and informing district AI policies. All of these outcomes reflect the TPCK framework. A few participants expressed the need for continued support during the upcoming academic year. Some felt overwhelmed by the number of tools introduced and which ones they should use. The majority of teachers expressed concern about their school's or district's lack of AI policies and how their school or district would address this issue but that they were better prepared to influence decisions once the school year began.

Conclusions

After soliciting applications from teachers in our existing partner districts, from teachers who attended our two conference presentations, and by sharing the opportunity on our website https://stem.northeastern.edu/grants/ai4k12teachers/, we have received over 40 applications to date for the 2026-2027 cohort. As of this writing, we are still waiting for NSF's decision about a supplement to increase funding to support additional teachers beyond the grant's initial target of 10 teachers per year. Otherwise, as originally planned, we will accept 8 – 10 new teachers to join our existing AI community of practice and expand our teachers' professional leadership communities, informed by the findings from our program evaluation and by the experiences and successes of our first practitioners.

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