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Integrating Design Thinking in a STEM Methods Course

Demetrice Smith-Mutegi
Old Dominion University

ABSTRACT

Design thinking, a problem-solving approach, has been offered as a strategy to address the challenges of growing and complex teaching expectations. This article describes an adapted model of design thinking that was implemented in a secondary STEM methods course for teacher candidates (TCs) in a graduate program. Design thinking, when implemented by teachers and TCs, allows for designing and improving a lesson or unit based on student feedback and engagement. This is especially important in today's rapidly evolving educational landscape, wherein educators must be adaptable and responsive to the diverse needs of their students. Empirical studies examining the use of this strategy are important for establishing further credibility to this approach.

Keywords: design thinking, preservice teachers, secondary teacher education, teacher candidates, STEM education

Introduction

The study of teaching and learning in STEM has long been a focal point in teacher education, emphasizing its significance in shaping effective educators and future STEM-ready citizens (Ledbetter, 2017; Zhang & Zhu, 2023). However, secondary school students often perceive STEM subjects as too difficult, unengaging, and lacking relevance (Morton & Smith-Mutegi, 2022; Musengimana et al., 2021; Osborne et al., 2003; Wen & Dubé, 2022). This perception presents both a real challenge and an opportunity for current and future STEM teachers (Guzey et al., 2026; Guzey et al., 2019). Various strategies and engagement techniques have been suggested to address this issue, including inquiry-based lessons and culturally relevant teaching strategies focused on relationship building (Hernandez, 2022; Liou, 2021). Education researchers call for more creative approaches to designing instructional lessons (Elwood & Jordan, 2022). According to A Framework for K-12 Science Education (2012), "In order for students to develop a sustained attraction to science and for them to appreciate the many ways in which it is pertinent to their daily lives, classroom learning experiences in science need to connect with their own interests and experiences." (p. 28).

Researchers have long emphasized the importance of adopting student-centered pedagogical approaches in STEM education (Granger et al., 2012). Among others, Ellis (et al., 2020), Radloff (et al., 2019), and Roehrig (et al., 2021) promote the implementation of design-based methods to engage preservice teachers in STEM disciplines with relevant tasks. Given the importance of STEM in diverse, educational settings, Brown and Livstrom (2020) proposed four teacher moves that support multicultural curriculum design, with the initial strategy focused on creating student-centered lessons based on student input. Accordingly, this article describes a strategy I implemented to support secondary STEM teacher candidates (TCs) in designing relevant, student-centered lessons that address the needs and interests of their STEM students.

The Design Thinking Process

Design thinking has been offered as an approach to address the challenges of growing and complex teaching expectations (Albay & Eisma, 2025; Elwood & Jordan, 2022; Henriksen et al., 2017; Koh et al., 2014). It is touted as a problem-solving approach grounded in constructivist learning theories that emphasizes learning from experiences, including specific design thinking processes such as empathizing, implementation, and iteration (Pande & Bharathi, 2020). In teacher education, design thinking will allow TCs "…to develop soft skills, apply this discipline properly in their future teaching work, and provide solutions to the complex problems they face in their daily work, such as creating instructional materials, lessons, and learning experiences" (Calavia et al., 2023, p. 3). Furthermore, design thinking supports the broader goals of STEM education and has been successfully implemented with students and practitioners across engineering disciplines and K-12 education (Li et al., 2019). Several frameworks and models have been designed to support this interactive process and have been implemented across various sectors, including business and education.

However, studies have primarily focused on the implementation of design thinking in K-12 classrooms with students as designers (Panke, 2019), and few focus on TCs. In a review of recent publications since 2021, eleven studies have been published on the topic of design thinking implemented in teacher education settings with PSTs or TCs (Avsec & Ferk Savec, 2022; Baran & AlZoubi, 2024; Calavia et al., 2023; Elsayary, 2022; Gleason & Jaramillo Cherrez, 2021; Lin et al., 2021; Liu et al., 2024; Özaydınlık, 2024; Wu et al., 2021; Zhu et al., 2024), with only three focusing on science and mathematics teaching. Four other studies focused on technology education, including a recent study exploring the role of artificial intelligence in design thinking skills among students in technology teacher education programs (Saritepeci & Yildiz Durak, 2024). Design thinking, when implemented with TCs, can enhance lesson design, creativity, and collaboration. According to Albay & Eisma (2025), in the context of lesson planning, design thinking can be a valuable tool for crafting more effective and engaging learning experiences for students. Henricksen and colleagues (2018) advance the notion that design thinking can support teachers' appreciation and value of empathy, increase their openness to uncertainty and failure, and view teaching as a design process. As part of my methods course, I incorporated design thinking, with the TC functioning as the designer and the K-12 students as the target audience or "users." Through this approach, the planning process for a unit or lesson began.

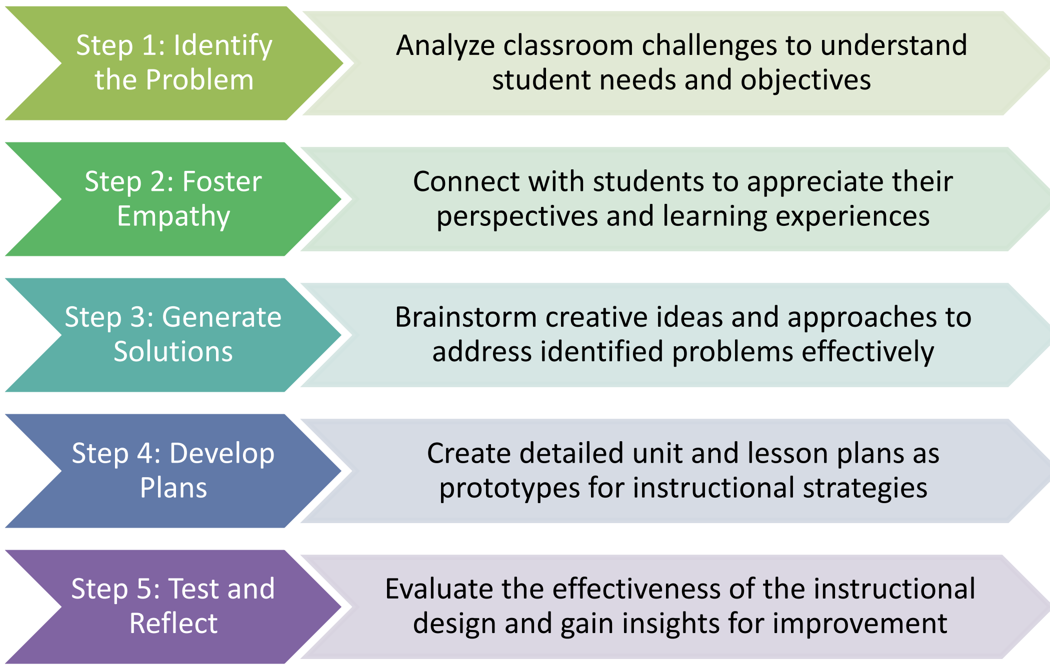
Design Thinking as a Strategy for Lesson Planning

At our university, we offer a combined methods course for TCs in secondary mathematics and science. As reported in prior research, this type of integration provides benefits but poses challenges for both instructors and students (Berlin & White, 2010). As an instructor of this newly integrated course, I decided to identify and leverage the commonalities among the TCs' experiences and perspectives in science and mathematics, as well explore the curriculum commonalities. Our course focused on interdisciplinary learning (Guzey et al., 2020), culturally sustaining pedagogies (Paris, 2012), and the integration of technology in secondary science and mathematics. I noticed that an increasing number of TCs reported struggling to understand or connect with students' behaviors, and that their students showed limited engagement during field experiences. Design thinking relies heavily on empathy, or understanding learners' needs and perspectives (Scheer et al., 2012). This led me to the work of design thinking and the practical implications for lesson design (Koh et al., 2015).

TCs should understand learners' prior knowledge, experiences, learning styles, and interests to plan lessons effectively using design thinking. Elwood & Jordan (2022) proposed the DTAIL model to address the nuances of applying the design thinking approach to lesson planning through five iterative stages: problem definition, perspective discovery, solution discovery, design testing, and reflective reframing. In a novel way, this model also offers TCs opportunities to reframe the problem, ultimately leading to a solution. In earlier models, such as the widely referenced Stanford d.school model, the constructs include empathizing, defining, ideation, prototype development, and testing. To address the challenges faced by current TCs, I integrated constructs from both models to concentrate on (1) problem-solving, (2) fostering empathy with students, (3) generating solutions or ideation, (4) developing unit and lesson plans as a form of prototyping, (5) testing the prototype, and (6) engaging in reflection (Figure 1).

Figure 1

Adapted Design Thinking Framework



Design thinking promotes creativity and innovation in the lesson planning process, enabling TCs to create more effective and engaging lessons (Albay & Eisma, 2025; Chen et al., 2023). Further, design thinking aligns with broader goals in STEM education through its interdisciplinary, collaborative, and human-centered characteristics (Ozturk, 2021). Through this approach, the goal was to enhance the candidates' effectiveness as future culturally competent educators.

The Implementation

In the following section, I will describe my implementation of the design thinking process with TCs enrolled in my secondary science and mathematics methods course. This course is a 3-hour synchronous online methods course that requires a 35-hour practicum in a local school science or mathematics classroom. After the pilot implementation, I revised the course structure to ensure that design thinking was not merely a topic introduced to students as a one-time event, but a concept practiced and embedded in the course. The course was structured around the following instructional skills: (1) developing inquiry-oriented lesson design skills, (2) designing lessons that enhance all students' STEM learning, and (3) engaging in reflective practitioner practice. Outcomes were assessed through unit and lesson plan rubrics, instructor and peer feedback, and mentor observations during the practicum. Figure 2 outlines the design thinking topics discussed in the course.

Figure 2
Design Thinking Course Integration

I. Introduction (Week 1)
- Brief introduction to and rationale for incorporating design thinking in the course

II. Understanding Design Thinking (Week 2)
- Define the concept of design thinking
- Explain the key steps of the design thinking process
- Share examples of design thinking in action

III. Applying Design Thinking in the Classroom (Week 2)
- Discuss how design thinking can be applied in the classroom
- Present examples of design thinking activities to incorporate into STEM lesson plans

IV. DT Practice (Week 3)
- Conduct an interactive activity that allows participants to experience the design thinking
- Debrief and discuss what participants learned from the activity

V. Integrating Design Thinking into Lesson Planning (Week 4-8)
- Discuss how design thinking can be integrated into existing Science and Math lesson plans
- Have teacher candidates brainstorm problems or issues in the STEM classroom
- Provide resources to help teachers integrate design thinking into their lesson planning
- Have TCs conduct empathy interviews and report findings of the empathy interviews
- Provide critical peer feedback

VI. Conclusion (Week 12)
- Recap the key points of the process
- Invite teacher candidates (and special guests) to share any final thoughts or questions.

To develop inquiry-oriented lesson design skills, students were introduced to foundational planning frameworks, including the 5E Instructional Model (Bybee et al., 2006) and the backward design framework for unit planning (Wiggins & McTighe, 2005). As designers of these unit plans, TCs were tasked with thinking through a unit topic in their subject area, along with the knowledge, skills, and appropriate assessment strategies. Further, TCs designed three lessons to accompany the unit plan. The unit plan was a culminating assignment that TCs submitted at the end of the course. Throughout the semester, TCs built and refined their unit plans through multiple draft submissions, peer feedback, and design thinking. Rather than designing complete units, some TCs used the process to refine existing curriculum or lessons when provided with them. These were typically unit or lesson plans developed by local school districts or lessons available at https://goopenva.org/.

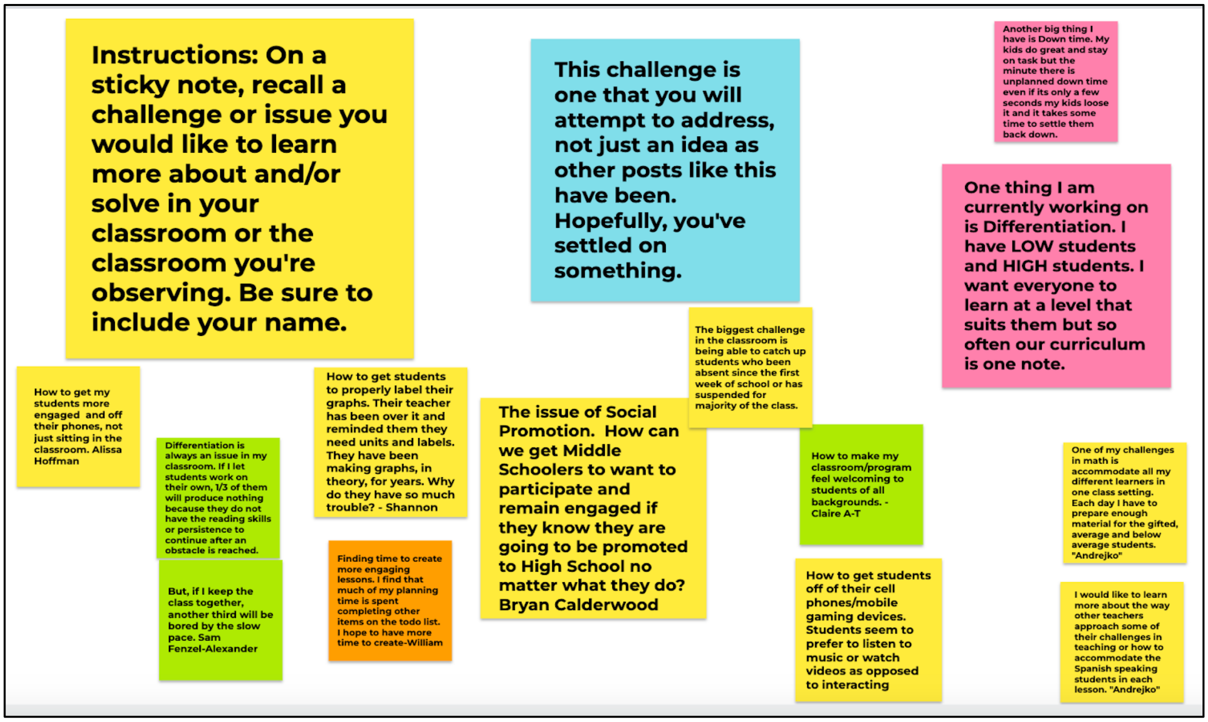
To begin the design thinking process, problem-solving is initiated with a brainstorm of challenges observed or perceived that could potentially be addressed by lesson design or implementation. One TC noted student engagement challenges during their field experience early on:

> Another surprise is how unmotivated many of these students are… In the first period their heads are already on their desks and the teacher must pump them up to get them motivated. When called upon most of the students just whisper or do not speak at all.

Figure 3 highlights other challenges noted by TCs during the class discussion and brainstorming sessions. Following this discussion, I introduced the unit plan as the future prototype to address some of their noticings and/or challenges observed in their field settings.

Figure 3

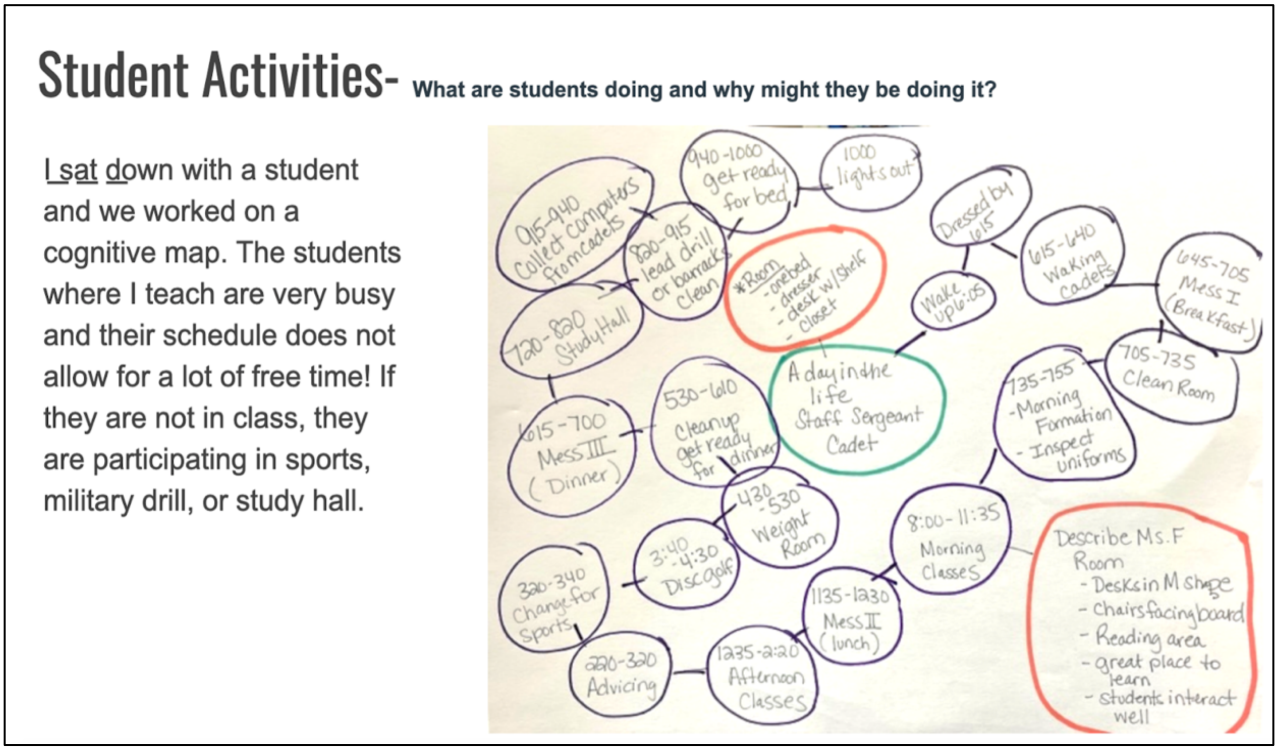
Virtual Whiteboard of TC Observations in the Field



After brainstorming and discussing problems that they observed in their classrooms, they selected an empathy interview protocol to implement. Empathy protocols were adapted from the Empathy Activities from the Co-Designing Schools Toolkit (available at https://www.codesigningschools.com/toolkit-phase-three). TCs implemented empathy protocols by choosing from a range of activities, with most opting for either the empathy interview or a time-lapse video recorded from the student's perspective. After the empathy activity, they shared their findings with peers during class time. One of the most valuable stages in the process for TCs was empathizing with their practicum students. One TC captured their notes as a cognitive map (Figure 4). These empathy activities enabled TCs to gain insight into students' prior knowledge, learning styles, experiences, and interests, ultimately allowing them to tailor lessons to each student's specific needs.

Figure 4

Empathy Activity: Cognitive Map



Once the empathy activities were conducted, TCs shared their findings through a brief presentation in our online class. The presentation required slides addressing each of the following questions from the Co-Designing Schools Empathy Activity Toolkit. During the presentations, they gathered feedback and initiated the ideation process.

- ACTIVITIES: What are students doing and why might they be doing it?
- ENVIRONMENTS: What space are you observing? What does it look like, and what's in it?
- INTERACTIONS: How are students interacting with others in this space?
- OBJECTS: What physical objects are in the space, and how are students using them?
- UNDERSTANDING: Based on what you've observed, what new insights or understanding have you gained? Were any ideas sparked?

The ideation process involved TCs applying an idea to an upcoming unit or lesson. After designing a prototype or plan, the TCs taught the lesson and recorded evidence of implementation. Recorded evidence provided TCs with data to aid in thoughtful reflection on the process. In most cases, the TCs were full-time teachers seeking teacher credentials through a graduate program for teacher licensure. Therefore, some were able to fully implement their prototypes and improve through several iterations. Teacher candidates have often commented on how valuable the empathetic experience was for their overall professional development. One TC stated:

> The results of the empathy project are what I am most proud of. I started interviewing two [students] so that I could complete the project. After seeing the connections that I made from those two interviews, I started interviewing two [students] a week to get to know the students on a different level.

Another TC reflected on their approach to center students in the design of science lessons and the resulting relationship with students. They shared, “I know my students are benefiting from good lesson plans... I even have few students who want to become teachers due to my close involvement of students in my lessons.” Some even reported continuing the empathy activities in their own classrooms after the course. At the end of the course, TCs published practitioner articles describing how they implemented their lessons following the design thinking exercises. From these articles, TCs’ concluding statements emphasized the value of student engagement and relevancy (Figures 5 and 6). Some of these lessons can be accessed at https://digitalcommons.odu.edu/inclusivestrategies/.

Figure 5

Science Teacher Candidate Conclusions After Teaching a Genetic Engineering Lesson

> By teaching this lesson, I have learned a great deal about adapting my teaching style to the needs and interests of my students. The first conclusion I have made based on my observations is that hands-on learning increases engagement and student learning. A student who rarely participates in class is more likely to participate during a hands-on learning experience. In general, students will become more excited about hands-on learning than they will about passive learning. This engagement in turn creates greater student learning and retention. Secondly, I noticed that individualized help during individual work time is beneficial to student understanding. When I taught this lesson in the past, students who didn’t understand the Bacterial Transformation Worksheet quickly gained understanding when I helped them connect the worksheet content to the Paper Plasmid Activity they had just completed. This ties back into connecting content material to hands-on learning experiences. Students understood what they did with the hands-on Paper Plasmid Activity, but they needed guidance to connect that information to the concepts on the Bacterial Transformation Worksheet. If let alone to make this connection, many students would fail. This is why it is important for teachers to have that one-on-one interaction with students during individual work time.

Science Teacher Candidate Conclusions After Teaching Lesson on Physical and Chemical Changes

pedagogy in their classroom by valuing diversity and collaboration.

The teacher used the Powtoon assignment to allow students to participate in the peer reviews and to

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The teacher used a variety of modes of instruction to further the student's level of understanding of physical and chemical changes and properties. Students were

given options for multiple ways to express what they know (King-Sears et al,. 2015). This lesson provided activities that incorporated culturally relevant pedagogy. The engagement activity offered students an opportunity to participate in a laboratory demonstration. Due to the student's prior knowledge of physical and chemical changes, they could predict what was going to occur during the demonstration. This activity caused students to be excited for the lesson that was to come. This excitement was contained throughout the lesson by the activities that followed.

There were many opportunities for the teacher to uphold a culturally relevant classroom. The teacher created an environment that allowed for collaboration between the students. Collaboration provides students with the opportunity to learn from their peers. The pairing of students with diverse backgrounds leads to hearing different perspectives. Also, at times throughout instruction, students were given the freedom to make their own decisions. By allowing students to make decisions about their education they are more likely to incorporate their interests and background (Goethe & Colina, 2018). By including these students will engage more in the lesson and assignment.

The peer review for the Powtoon assignment was a major aspect of the lesson. These peer reviews led to students being able to work on skills that are needed within the community. The teacher provided students with the directions, "Comments should be respectful, appropriate, and constructive." This allowed students to improve communication skills, collaboration skills, and critical thinking skills.

The teacher ended the lesson with a summative assessment and considered academic differentiation. This assessment was given in different formats to account for different learners. Throughout the lesson, cultural and academic differentiations need to be considered to ensure that every student feels that they can learn in the classroom. It is also important to ensure that teachers provide students with a positive and welcoming classroom where they can ask questions. This type of classroom allows students to feel comfortable and provides an environment that is best for learning.

Conclusions

In summary, design thinking can play a role in lesson planning by providing a structure for understanding the students' needs and perspectives, experimenting with different teaching methods, and adapting the lesson based on students' feedback (Baran & AlZoubi, 2023; Calavia et al., 2023). It also encourages innovation and creativity in lesson design, making the learning experience more engaging and effective for students. This model is not only a valuable tool for TCs but also applicable to reflective in-service practitioners seeking to enhance their lessons based on student needs. Since the initial iteration of design thinking, the implementation has changed slightly.

In Calavia et al.'s (2023) study of design thinking and project-based learning with preservice teachers, they assert that practical solutions for training are necessary to enhance the concept of teachers as designers. Therefore, teacher educators interested in implementing design thinking in methods courses should consider the following (1) existing course activities and assignments—assess the feasibility of integrating, replacing, or adding new activities and assignments to your existing course, (2) TC access to students—consider when and if TCs will have access to students in order to conduct the empathy activities, and (3) overall expectations and goals from implementing—determine what you hope or expect your TCs will take away from this experience that they may not gain through traditional course activities and assessments. Initially, I collaborated with a colleague in our college's educational leadership program. The colleague invited her school leadership interns to partner with my TCs to process the findings of the empathy activities project. This collaboration offered TCs the opportunity to hear from current and future school leaders, empowering them to take the next steps in the process. While fruitful, this collaboration was not available in the following iterations. This experience has taught me to engage in the design thinking process with my TCs with an open mind. It is important to acknowledge that not every iteration will look the same, and not every TC will walk away from the experience with the same ideas.

With a focus on STEM teacher candidates, the work presented here is an extension of recent scholarship exploring design thinking in preservice teaching classrooms (Baran & AlZoubi, 2024; Calavia et al., 2023; Chen et al., 2023; Liu et al., 2024). By thinking outside the box and trying new approaches, TCs can create lessons that are more engaging and effective for all students. Although this narrative did not incorporate empirical data, it is recommended that future research and practice investigate the influence of the design thinking process on STEM education teachers' curriculum development as they tackle evolving and emerging challenges in education, such as integrating AI, addressing diverse classroom settings, and managing resource constraints. Studies such as Saritepeci and Yıldız Durak (2024) show the promise of design-oriented approaches supported by AI tools for strengthening reflective, creative, and adaptive skill sets in STEM TCs.

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