Exploring Preservice Teachers' Design Thinking Mindset in a Technology-Enhanced Active Learning Environment for STEM Courses

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Abstract

This study explores how a technology-enhanced active learning environment, supported by interactive technologies, may influence preservice teachers' perceptions of their design thinking (DT) mindsets in interdisciplinary STEM courses. Using a blend of digital tools and the design thinking process, the research aimed to engage students in activities that promote key DT traits, including managing uncertainty, empathy, mindfulness, collaboration, learning orientation, and creative confidence. Ninety-four preservice teachers from an early childhood education program in a UAE university participated, receiving two weeks of intensive training on digital tools (e.g., Genially, Canva, PowToon, AR/VR apps), concluding in earning an Apple Teaching Certificate. These tools were later utilized to facilitate key components of the DT process, including user empathy, iterative prototyping, and collaborative challenge design, thereby directly supporting the development of DT mindsets within a technology-enhanced framework. This study employed an explanatory sequential mixed-methods approach, beginning with quantitative analysis (mean, standard deviation, and one-sample t-test) and followed by qualitative insights from focus groups. Findings suggest a perceived positive shift across all DT mindset categories, with students reporting enhanced confidence in tackling complex challenges using technology-driven and collaborative techniques. These results should be interpreted with caution due to the absence of baseline (pre-test) data. Nevertheless, they highlight the potential of technology-enhanced active learning frameworks to support the development of mindsets revealed to be effective in STEM education.

Keywords: Design thinking mindset, technology-enhanced active learning environment, interdisciplinary STEM courses, transformative learning, technological pedagogical content knowledge

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In a rapidly evolving and interconnected world, education systems must adapt to meet the diverse needs of various cultures and societies. Individuals must receive a high-quality education that is meaningful and relevant to their cultural or geographical context (UNESCO, 2016). Educational transformation aims to develop learners both academically, socially, and spiritually (Khoo & Jørgensen, 2021) and prepare them for future careers that may not exist (Khoo & Jørgensen, 2021). International organizations such as UNESCO, the Organization for Economic Co-operation and Development (OECD), Partnership for 21st Century Skills (P21), and Assessment and Teaching of the 21st Century Skills emphasize the urgent need to integrate 21st-century competencies, such as collaboration, creativity, digital literacy, and adaptability, into education (González-Salamanca et al., 2020). Some experts argue that the rapid advancement in digitalization may lead to a faster rate of job loss than job creation (Schleicher, 2018). On the contrary, the emergence of the "knowledge economy" concept reflects a shift towards new job types that demand expertise in communication, systems, or interpersonal skills (Capone & Leopre, 2021).

In the Gulf region, many nations, including the United Arab Emirates (UAE), are transitioning from dependence on oil to building a knowledge-based economy. One of the UAE's core national priorities under the 2030 Agenda for Sustainable Development is educational reform aimed at equipping future generations with the skills required for this transition (UAE National Committee on SDGs, 2017). A key performance indicator within this agenda is increasing the proportion of highly qualified teachers, reflecting the nation's commitment to improving teaching quality as a driver of sustainable development (UAE National Committee on SDGs, 2017). In alignment with the UAE Science, Technology, and Innovation Policy (STI), this research aims to increase interdisciplinary STEM talents among Emirati students (UAE Government, 2015). To prepare students to acquire the essential skills for future jobs, including those shaped by automation and digital transformation, curriculum reform that integrates technology-enhanced learning approaches is essential (UAE Ministry of Education, 2017). In the 2019/2020 World Education Forum (WEF) report, the UAE was rated slightly above average in areas related to 21st-century readiness. These skills include active learning, leadership, analytical thinking and creativity, technology use, and self-direction (Schwab & Zahidi, 2020).

Science, Technology, Engineering, and Mathematics (STEM) education is an interdisciplinary model that integrates multiple disciplines to promote problem-solving, innovation, and real-world application through student-centered learning (Hsu & Tsai, 2022). The interdisciplinary STEM model aims to engage students with real-world applications, fostering an inquiry-based mindset and problem-solving skills essential for the 21st century (Chai et al., 2020). STEM integrates scientific subjects, while the "A" in STEAM refers to the non-scientific subjects. Understanding the interconnections between these domains is critical: Science is reflected in hands-on exploration, technology is in the project-based tools, engineering through Design Thinking (DT), art through creative products, and mathematics via modeling and abstraction (ElSayary et al., 2015). Additionally, a broader integration model, STrEAM, which includes reading, has been piloted in UAE government schools to further promote literacy alongside STEM learning. As science and technology continue to evolve rapidly, educators must adapt to new teaching demands, requiring both technical fluency and mindset shifts among teachers and students alike (Capone & Lepore, 2021). Technology plays a pivotal role in supporting STEM instruction by enhancing interactivity, creativity, and interdisciplinary problem-solving. Moreover, research suggests that technology can deepen educators' understanding of the design-thinking process by enabling creative experimentation and iterative solution-building (Novak & Mulvey, 2020). While not solely responsible for the development of DT mindsets, technology-enhanced learning environments can significantly contribute to their cultivation by fostering collaboration, adaptability, and reflective thinking.

Design-thinking (DT) is a human-centered innovation approach inspired by how design thinkers from multiple disciplines understand individuals' needs, rapid prototyping, and generate innovative ideas that will change how individuals develop products, services, processes, and organizations (Simeon et al., 2020). It has been viewed as approaching integrated problems in the curriculum where incorporating technology into pedagogy improves teachers' professionalism (Noh & AbdulKarim, 2021). Students' ability to develop essential STEM competencies depends on their teachers' expertise in integrating technology and interdisciplinary learning. To foster creativity and problem-solving, teachers must first promote a DT mindset, which encourages adaptability, collaboration, and innovation. This shift requires moving beyond traditional teaching methods toward designing a technology-enhanced active learning environment where students actively engage with digital tools to construct knowledge. Developing a DT mindset among teachers is particularly critical, as it directly influences students' creative confidence and ability to tackle problems.

While previous research on DT primarily focused on business (Xiao et al., 2023), engineering (Dagienė et al., 2022), and design and planning fields (Lachheb et al., 2023), its application in education remains an emerging area of study (Henriksen et al., 2020; VanGronigen et al., 2022). Recent studies highlight its potential to transform teaching practices, yet the integration of DT in technology-enhanced active learning environments, particularly in STEM education, remains underexplored. Current research lacks insights into how DT mindsets evolve through interactive digital pedagogies and how they impact interdisciplinary STEM learning outcomes (Hite et al., 2024). This study employs a technology-enhanced active learning framework (TEALF), which integrates digital tools, interactive pedagogies, and collaborative problem-solving approaches. This framework aims to promote a perceived shift in design-thinking mindset among pre-service teachers within STEM education. The framework aligns with the Technological Pedagogical Content Knowledge (TPACK) model and transformative learning principles, ensuring technology is not merely an instructional supplement but an integral component of active learning engagement. Accordingly, this study explores the impact of using a TEALF on preservice teachers' DT mindset. The study aims to answer the following questions that would address the main aim of the study:

1. How do preservice teachers perceive their Design Thinking mindset after engaging in a Technology-Enhanced Active Learning Environment in STEM courses?

2. What are the preservice teachers' perceptions of using the technology-enhanced active learning design framework in STEM courses?

Literature Review

Theoretical Framework

One of the well-known frameworks used to conceptualize and guide technology integration in teacher education is the Technological Pedagogical Content Knowledge (TPACK) framework, which was developed to provide teachers with the necessary knowledge to plan technology-integrated lessons (Koheler et al., 2014). The TPACK framework integrates content, pedagogical, and technological knowledge, providing a foundation for effective technology-enhanced learning (Novak & Mulvey, 2020; Vijayatheepan, 2025). In this study, the Technology-Enhanced Learning Framework (TEALF) operationalizes TPACK by equipping pre-service teachers with hands-on experience using digital tools within interdisciplinary STEM contexts, with the explicit aim of fostering habits of mind associated with design thinking. Gess-Newsom (1999) differentiated between integrative and transformative applications of TPACK. The integrative approach merges the content, pedagogical, and technological knowledge within the traditional framework of teaching and learning. The integrative approach emphasizes the use of technology to enhance conventional teaching and learning methods without fundamentally altering them. In contrast, the transformative approach, which aligns with Mezirow's (1997) transformative learning theory, goes beyond mere integration; it aims to fundamentally change or redefine the teaching and learning experience through innovative technology (Capone & Lepore, 2021). This study adopts the transformative lens, positioning TEALF not merely as a tool for instructional efficiency but as a mechanism to disrupt habitual thinking and promote reflective, student-centered design practices in future STEM classrooms. Moreover, the focus on the DT mindset rather than the process is intentional and central to the study's conceptual framework. As Elsbach and Stigliani (2018) argue, mindset encompasses the cognitive, affective, and behavioral dispositions that enable individuals to approach challenges with empathy, creativity, and openness, skills particularly crucial for preservice teachers who must design for diverse early learners in interdisciplinary contexts. This emphasis informed both the design of the intervention, which embedded technology in reflective, collaborative, and ill-defined problem scenarios, and the selection of the measurement instrument, which assesses DT mindsets such as empathy, uncertainty tolerance, mindfulness, and creative confidence. By grounding the TEALF within both TPACK and transformative learning theory, this study frames DT not as a technical procedure but as a way of thinking that technology can help cultivate in meaningful, contextually responsive ways.

Mezirow's Transformative Learning Theory (TLT) (1997) emphasizes the process by which individuals critically assess their assumptions, engage in reflective discourse, and ultimately transform their frames of reference, particularly when faced with unfamiliar, uncomfortable, or disorienting experiences. Key elements of TLT include encountering a disorienting dilemma, engaging in critical reflection, participating in dialogue, and gradually adopting new perspectives or habits of mind (Strange & Gibson, 2017). These processes are especially relevant in teacher education, where preservice teachers must question traditional pedagogies and embrace learner-centered approaches grounded in inquiry, creativity, and adaptability.

In this study, the TEALF was deliberately designed to foster transformative learning by immersing preservice teachers in new digital learning environments, requiring them to navigate ambiguity, collaborate in diverse teams, and design interdisciplinary STEM solutions using unfamiliar technological tools. The study's findings demonstrate that participants experienced cognitive and perspective transformation, reinforcing Mezirow's assertion that transformative learning occurs when individuals engage in self-directed, reflective practice in unfamiliar contexts. In transformative learning, individuals question their perspectives, particularly in uncomfortable situations, thereby transforming their frame of reference, including their points of view and habits of mind (Strange & Gibson, 2017). The 2020 lockdown, an unexpected and uncomfortable situation, forced educators and learners worldwide to rethink and transform their educational practices, aligning with the principles of Mezirow's theory (Bao, 2020; Trust & Whalen, 2020). TEALF operationalizes transformative learning theory by structuring learning experiences that challenge habitual thinking and provoke identity shifts, moving learners from passive knowledge receivers to active, reflective designers. This theoretical alignment positions transformative learning not only as a desired outcome but as an embedded mechanism within the instructional design of the intervention.

The global disruption caused by COVID-19 exposed deep systemic challenges in education that extend far beyond temporary learning gaps. It accelerated the need for flexible, learner-centered approaches that integrate technology meaningfully into pedagogical design. This study addresses the need by integrating the DT process into a TEALF, positioning technology not as an add-on, but as an enabler of collaborative problem-solving and creative exploration within STEM education. Mainly, preservice teachers in the study used the DT process in two contexts: as learners designing solutions to interdisciplinary challenges using digital tools, and as future educators applying these same processes to design developmentally appropriate STEM experiences for children enrolled in early childhood education programs. This dual-context application provided rich opportunities for reflective practice and role-shifting, key features of transformative learning. Integrating DT within TEALF also reflects a deliberate alignment with the transformative dimension of the TPACK framework and Mezirow's transformative learning theory (ElSayary et al., 2022). The use of unfamiliar technologies, the collaborative resolution of complex and ill-structured problems, and the emphasis on iterative feedback loops required preservice teachers to re-evaluate prior assumptions about teaching and learning. In doing so, the framework encouraged them to engage in critical reflection, embrace uncertainty, and shift from traditional instructional habits toward more empathetic, learner-responsive design approaches.

Design Thinking (DT) Mindset

The DT mindset, a concept gaining traction in educational research, encapsulates a set of cognitive, emotional, and behavioral traits that support innovative, human-centered problem-solving. At its core, the DT mindset emphasizes qualities such as empathy, creativity, collaboration, adaptability, and reflective learning. Kimbell and Seidel (2019) argue that DT is a mindset that emphasizes empathy, creativity, and collaboration and can be applied across various educational contexts. Another recent study has elaborated on various facets of this mindset, emphasizing its role in fostering creativity, adaptability, and reflective practice in academic settings (ElSayary et al., 2022). Valencia et al. (2021) and Auernhammer et al. (2022) expand this view, highlighting key traits, openness, empathy, intrinsic motivation, mindfulness, adjustment, and optimism, that underlie the DT mindset and support learner adaptability in complex scenarios. This multidimensional perspective is echoed across multiple studies. For example, Alashwal (2020) and Li and Zhan (2022) emphasize the importance of comfort with *uncertainty* and ill-defined problems, a hallmark of creative resilience and systems thinking. Loderer & Kock (2021) and Vignoli et al. (2023) similarly link uncertainty tolerance to the mindset's exploratory nature, noting that design thinkers actively seek novel possibilities in ambiguous contexts. User *empathy*, another cornerstone of DT, has been extensively studied. Altay and Porter (2021) and Noh and AbdulKarim (2021) found that empathy not only fosters inclusivity and perspective-taking but also leads to less judgmental and more inclusive design processes. Additionally, a study by Adams and Brown (2017) demonstrated how empathy enhances collaborative efforts in design teams. *Mindfulness,* as discussed by Vignoli et al. (2023) and Patel and Kumar (2018), supports DT by enhancing learners' metacognitive awareness and their ability to navigate complex, iterative processes. Collaboration remains central to DT, particularly in interdisciplinary environments. Henriksen et al. (2022) and Groeger and Schweitzer (2020) argue that *collaborative* diversity facilitates idea generation, collective knowledge construction, and visualization, critical elements in problem-based learning. Equally important is the concept of *learning orientation,* or the sustained motivation to engage with new knowledge. Simeon et al. (2020) observe that this orientation underpins the iterative, growth-focused nature of DT, enabling learners to learn from failure and adapt solutions in real-time. Finally, *creative confidence*, the belief in one's capacity to generate novel ideas and solutions, is recognized as a fundamental DT trait. Hamat et al. (2019) popularized the term, and Henriksen et al. (2020) found that creative confidence has a significant influence on problem-solving effectiveness in design teams. As conducted by Kwek & Toh (2020), Liu (2023), and Yilmaz-Soylu et al. (2021), DT fosters a holistic suite of skills, including empathy, creativity, problem-solving, and collaboration skills, that make it a promising pedagogical approach for preparing learners to navigate the complex challenges of 21st-century education.

Technology-Enhanced Active Learning Environment

A technology-enhanced active learning environment is characterized by the purposeful integration of interactive technologies to foster learner engagement, critical thinking, and transferable skills such as collaboration, self-direction, and creativity. Several researchers defined a technology-enhanced active learning environment; for instance, Hite et al. (2024) mentioned that when students actively engage with information, they activate their existing knowledge of the topic to encode new information in a virtual learning environment (VLE). Similarly, Gar & Idris (2021) described technology-enhanced learning as a space where immersive and interactive technology enhances students' cognitive engagement through exploration and interaction. In the present study, a technology-enhanced learning environment is conceptualized as a framework that supports the development of 21st-century competencies, such as computational thinking, innovation, and collaboration, by embedding technology into meaningful, learner-centered tasks.

However, implementing technology-enhanced learning is not without challenges. Rybakova et al. (2021) noted that the absence of human interactions and the excessive, unplanned use of digital connectivity can lead to a sense of isolation and reduced motivation. When students are mindful of the independent use of technology, they avoid isolation and build a sense of satisfaction as they research information, criticize and empathize, collaborate with others, solve complex problems, orient their learning process, and suggest creative solutions. Supporting this concern, Novak and Mulvey (2020) noted that students who opted to drop out of technology-enhanced active learning courses reported significantly lower satisfaction with this approach compared to students who took on-campus courses. When technology tools are used appropriately, they improve individuals' lives by giving them access to information and the opportunity to solve complex real-world problems (Hirsh & Baronak, 2020).

When implemented effectively, a technology-enhanced active learning environment is a process that encourages students to take the lead in their learning (Abykanova et al., 2016). It fosters a collaborative learning environment in which they can communicate with one another (Rybakova et al., 2021). These features are further enhanced in STEM education, which significantly shifts from traditional teaching methods, focusing on active learning *where* students engage in hands-on, practical problem-solving (Tey et al., 2020). When learners use information, research, solve ill-structured problems, empathize with individuals' needs, and create new products, they build creative confidence, become innovative, and become mindful of their learning process (Abykanova et al., 2016). Furthermore, collaborative projects are integral, fostering teamwork and communication skills that mirror future workplace environments (Vennix et al., 2022). In this way, technology functions not merely as a delivery tool but as a core enabler of inquiry, creativity, and skill transfer. Additionally, technology is a tool and also a central element of learning, enhancing interactivity and preparing students for a tech-centric world (Abykanova et al., 2016; ElSayary et al., 2022), which leads to a perceived shift in learners' DT mindsets (Daniela et al., 2018; Scanlon et al., 2019). These active engagement strategies, teamwork, and technological integration collectively address the diverse needs and skills required for success in today's rapidly evolving global landscape (Chai et al., 2020). Empirical examples illustrate how TEALF supports interdisciplinary learning. For instance, a robotics project inspired by Hsu & Tsai (2022) engages students in applying mathematical theories and engineering principles, utilizing technology as an integral component of learning, and programming robots to perform tasks that require a blend of these disciplines. Drawing on a study by He (2023), students combined artistic creativity with scientific principles, using technology for design and mathematics for structural calculations, thereby enriching the learning experience and fostering analytical and creative skills. In another study by Zuhaida et al. (2022), students delved into science using interactive technology for data collection, applying mathematical models and engineering solutions to real-world ecological issues, demonstrating the potential of TEALF to unify diverse disciplines around meaningful challenges.

Methodology

This study employed an explanatory sequential mixed-methods design beginning with a post-intervention survey administered to 94 preservice teachers enrolled in an early childhood education program. The survey aimed to assess perceived shift in their Design Thinking (DT) mindsets following the full implementation of the Technology-Enhanced Active Learning Framework (TEALF) framework. A pre-test was not conducted, as the focus was on evaluating the outcomes of the TEALF after its full implementation rather than tracking incremental changes over time. Additionally, prior studies indicate that pre-tests in similar pedagogical interventions can introduce response bias, as participants may not fully grasp the constructs being measured for the intervention (Johnson & Christensen, 2014). Following the post-test survey, focus groups were conducted to provide deeper insights into the quantitative findings. The quantitative analysis revealed perceived shifts in all six DT mindset categories (uncertainty, empathy, mindfulness, collaboration, learning orientation, and creative confidence), but it did not capture the underlying reasons for these changes. The qualitative phase was therefore designed to explore how preservice teachers experienced these transformations, the challenges they encountered, and their perceptions of using the TEALF in STEM education. This design follows Creswell and Clark’s (2017) explanatory sequential mixed-methods framework, in which quantitative results are analyzed first and then further explained and expanded through qualitative data. Mixed-methods designs are helpful in mitigating biases that may be present when relying solely on one approach (Johnson & Christensen, 2014). The quantitative data aimed to understand the impact on learners’ learning, while the qualitative data were used to gain a deeper understanding of the phenomenon of participants’ perceptions.

Participants

The intended sample size was 120 preservice teachers studying in an early childhood program at a federal university in the UAE. The final purposeful sample consisted of 94 participants who met the predefined criteria: they were enrolled in semesters 4-8, registered in Practicum I, II, or III courses, attended Math, Science, Technology, and Integrated Curriculum courses, and expressed a willingness to participate in the study. Those who did not meet the criteria were excluded from the study. The participants were 100% female students between 18 and 25 years old, as the program does not accept male students. Before conducting the study, participants were fully informed of the study’s purpose and procedures. They were advised of their right to withdraw at any time without penalty, in line with ethical research standards. Informed consent was obtained, and anonymity of all survey and focus group responses was assured. Following the survey, preservice teachers were invited to participate in focus groups to elaborate on their learning experiences with TEALF. Participants were selected based on their willingness to engage in reflective discussions and their varied experiences with the framework. A total of twelve students participated in two focus group sessions, each with six participants, ensuring diverse perspectives from different levels of engagement with the technology-enhanced learning environment. The discussions followed a semi-structured format, exploring four key themes: challenges faced when adopting the TEALF, the evolution of DT mindsets, the perceived impact on their teaching practices, and recommendations for improving the framework.

Context of the Study

This study was conducted at a federal university in the UAE, which is recognized nationally and regionally for its educational innovation. The preservice teachers enrolled in an early childhood education program that follows a semester-based structure, integrating academic studies, practicum, STEM, and elective courses. Instructors are specialized in STEM education and were certified as Apple Teachers and Certified Online Instructors. The courses employed a blended learning approach, emphasizing the use of technology and the DT process to support preservice teachers in creating STEM-based instructional materials for childhood education students. Practicum assignments involved direct, hands-on teaching practice in school settings and were designed to allow preservice teachers to implement the DT process as both learners and emerging educators. At the start of the semester, preservice teachers completed a two-week training on various applications, including iCloud Apps, Genially, Canva, Doodly, PowToon, as well as tools for augmented reality and virtual reality. They earned Apple Teaching Certificates and developed e-portfolios showcasing their teaching materials. This training prepared them to apply the DT process and integrate technology in their practicum courses, where they designed and taught STEM challenges to childhood education students. Practicum placements included private and government schools across various curricula, including American, British, the UAE's Ministry of Education, and International Baccalaureate (IB) programs.

Instruments

Pre-Service Teachers Survey

The preservice teachers' survey was used to investigate the impact of using technology in a technology-enhanced active learning environment on exploring preservice teachers' design-thinking mindsets. The survey focused on six dependent variables associated with the DT mindset: uncertainty, empathy, mindfulness, collaboration with others, learning orientation, and creative confidence. The survey consisted of two sections: demographic information, where the selection criteria were set, and DT mindset categories. It included multiple-choice questions to ask preservice teachers about the age range, semester enrolled in, STEM courses registered, and practicum courses registered. The second section of the survey comprised items targeting the six DT mindsets dimensions. The scale used in the survey was a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

The DT mindset items were adapted from a previously validated instrument (ElSayary et al., 2022) to suit the local educational and cultural context of the UAE. Adaptations included simplifying technical terminology, aligning item language with regional educational standards, and rephrasing items for clarity when translated into Arabic.

For content validity purposes, the adapted survey was reviewed by two educational experts with doctoral qualifications in curriculum and instruction and extensive experience in teacher education and instructional design. Their feedback focused on item clarity, cultural appropriateness, and the language suitability for non-native English speakers. Based on their input, several minor wording changes were implemented, and the entire instrument was translated into Arabic to ensure accurate interpretation by the target sample. To evaluate the instrument's reliability before main data collection, the revised survey was piloted with 30 in-service early childhood teachers from a similar demographic background to the study's target population. These participants were not part of the main study.

The reliability test using Cronbach's Alpha was run to assess internal consistency. The reliability values for each of the six DT mindset categories were $\alpha = 0.98$, and the overall instrument reliability was $\alpha = 0.99$, indicating excellent consistency ($\alpha > 0.9$). These results confirmed the instrument's suitability for use in the current study. The reliability test was measured again with all samples, and the results remained highly consistent across categories (from $\alpha=0.93$ to $\alpha=0.98$) and overall ($\alpha=0.99$).

Focus Group Discussion

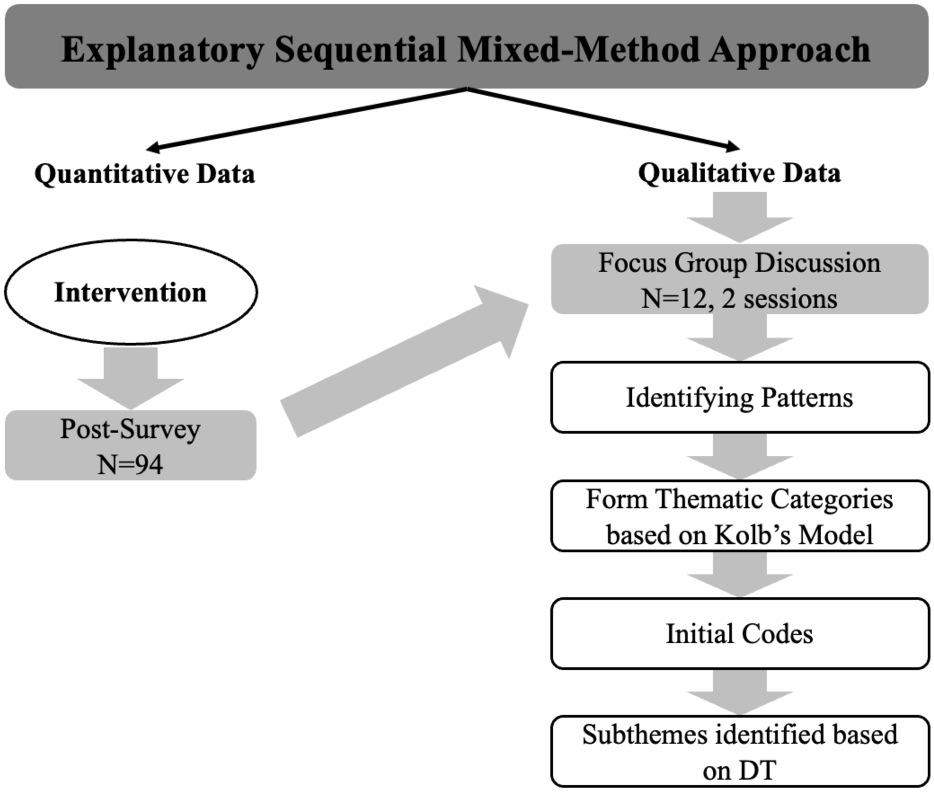
Focus group discussions were conducted via Zoom conference and averaged approximately forty-five minutes each. The interview protocol was designed using Kolb's (1984) experiential learning model to guide the structure and thematic flow of the conversations. Kolb's model consists of four cyclical stages: Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation, each of which informs one of the main categories used to frame the focus group questions. This theoretical foundation ensured that participants were guided through a process of reflecting on their lived experiences, interpreting their meaning, and envisioning future improvements. To assess the face validity and clarity of the questions, the draft protocol was reviewed by an educational expert and two STEM instructors not involved in the study. Their suggestions led to the merging of overlapping questions and the refinement of language to ensure accessibility and comprehension for the target participants. The final set of open-ended questions after editing included prompts that asked participants to decribe the experience using technology in the DT process (*Concrete Experience*), reflect on how it influenced their thinking and professional views on early childhood STEM education (*Reflective Observation*), evaluate the positive aspects and challenges of the experience (*Abstract Conceptualization*), and consider what they might do differently in the future and why (*Active Experimentation*). These questions were designed to elicit deep, personal insights into how the TEALF shaped participants' learning processes and Design Thinking mindsets.

Procedure

The study adopted an explanatory sequential mixed-method design, in which quantitative data collection and analysis were conducted first, followed by qualitative data collection to provide a deeper insight into the qualitative results (Creswell & Clark, 2017). While the term methodological triangulation is sometimes used to describe the use of multiple methods in a single study, the present design primarily sought to elaborate on statistical patterns through participants' reflections, rather than to cross-validate parallel measures of the same construct. Thus, the qualitative phase offered a complementary perspective that enriched the interpretation of the initial findings. First, the quantitative data approach was employed to answer the study's first question: *How do preservice teachers perceive their Design Thinking mindset after engaging in a technology-enhanced active learning environment (TEALF) in STEM courses? This was achieved* using a one-sample t-test. The subsequent qualitative phase was employed to address the second question of the study: *What are the preservice teachers' perceptions of using the technology-enhanced active learning design framework in STEM courses?* This phase involved focus group discussions that explored learners' experiences and perceptions of the intervention. The integration of findings enabled a more comprehensive understanding of the impact and perceived value of TEALF in fostering DT mindsets within interdisciplinary STEM education. Figure 1 illustrates the flow of the data collection of the study design. The following sections provide a detailed explanation of the data collection and analysis for each method.

Figure 1

The Study Design Follows an Explanatory Sequential Mixed-Method Design



Quantitative Data Collection & Analysis

At the beginning of the semester, participants received a consent form that provided a full explanation of the study's purpose, procedures, and their rights as participants. Data collection for the quantitative phase was conducted at the end of the semester, when participants received a link to complete the post-intervention survey. The survey responses were then analyzed using both descriptive and inferential statistics to examine participants' perceptions of their Design Thinking (DT) mindsets after engaging with the TEALF. Descriptive statistics, including means and standard deviations, were calculated for each of the six DT mindset subscales to summarize participants' responses and identify general trends. To determine whether the assumptions for inferential testing were met, Q-Q plots were generated for each subscale to assess the normality of the data distribution. These visual inspections were supported by standard normality tests, which confirmed that the data approximated a normal distribution. Based on these findings, a one-sample t-test was conducted to determine whether the mean scores for each DT mindset dimension differed significantly from the neutral midpoint value of 3.0 on the 5-point Likert scale. This analytical approach provided an appropriate method for assessing whether participants perceived a meaningful shift in their DT mindset following the intervention, but it does not measure change over time. As no pre-test was conducted, this method cannot establish causal claims or quantify actual growth resulting from the TEALF intervention. The decision to use $m = 3$ as the comparison point aligns with established interpretations of Likert-scale midpoints as indicators of neutral or baseline perceptions (Handal et al., 2013). While the World Bank (2021) highlights the importance of fostering growth mindsets and an intermediate level of competence among educators globally, its application here serves only as a broad contextual benchmark, not a direct validation of the DT scale. Thus, any significant deviations from m = 3 in this study should be interpreted as indicative of perceived positive orientation toward DT mindset traits, rather than definitive evidence of development or intervention impact.

Qualitative Data Collection & Analysis

Focus group discussions were conducted following the quantitative data collection to delve deeper into participants' perceptions and to further explore patterns emerging from the initial data. The survey results indicated varying levels of agreement across different dimensions of the DT mindset, with particularly high scores in learning orientation and collaboration, and lower mean scores in creative confidence and empathy. These quantitative trends informed the design of the focus group questions, prompting the researchers to probe more deeply into the factors contributing to participants’ confidence, challenges with creativity, and their experiences of collaboration and uncertainty in practice. The questions were framed to elicit reflective accounts that could explain or contextualize the statistical outcomes. Each discussion session on Zoom lasted 30-60 minutes, with an average duration of 45 minutes. Participant responses were transcribed and subjected to thematic analysis to enrich and elaborate upon the quantitative findings. This mixed-method approach ensured that the qualitative phase directly responded to key findings from the survey and provided a more detailed understanding of how preservice teachers perceived and experienced the influence of the TEALF on their DT mindsets. This study employed a thematic analysis approach following the six-phase approach outlined by Braun & Clarke (2006) to systematically examine patterns within the qualitative data. The process began with familiarization, during which the researcher transcribed and repeatedly read the focus group data to become immersed in the content. The researcher organized the qualitative data using four experiential categories: (1) Descriptions, (2) Feelings, (3) Evaluations, and (4) Conclusions and Plans, which were directly informed by Kolb’s (1984) experiential learning cycle. These categories reflected the structure of the focus group questions and served as an initial framework to explore how preservice teachers made sense of their learning. Next, initial codes were generated to identify meaningful features related to participants’ experiences with the TEALF and its influence on their DT mindsets. In other words, within each category, the researcher identified patterns that aligned with six core traits of the DT mindset: Uncertainty, Empathy, Mindfulness, Collaboration, Learning Orientation, and Creative Confidence. In the third phase, these codes were collated and organized into potential sub-themes, enabling the mapping of emerging patterns across the dataset. During the reviewing phase, these preliminary sub-themes were refined to ensure they accurately represented both the coded extracts and the full data set. The final stage was report production, where illustrative quotes and interpretations were developed to convey the findings. This approach ensured a coherent progression from guided experiential reflection to the identification of mindset-specific perceptions, providing a detailed understanding of how TEALF shaped preservice teachers’ perceptions of DT mindsets.

Qualitative data were manually coded using an iterative and reflexive process that involved multiple readings of each transcript to ensure deep engagement with the content. During the initial phase, two independent researchers generated preliminary codes separately, drawing on both the research questions and emergent insights from the data. These initial code lists were then compared and refined through discussion to create a shared coding framework. The researchers used this framework to recode the transcripts, followed by additional rounds of review and refinement to ensure alignment with emerging patterns and theoretical constructs. To enhance researcher triangulation, the coders not only worked independently during the initial phases but also held regular debriefing sessions to discuss their interpretations, challenge assumptions, and refine theme development collaboratively. This ongoing dialogue supported a deeper interpretive process and helped maintain analytic consistency. To further establish intercoder reliability, Cohen's kappa was calculated, yielding a substantial agreement score of 0.82, in line with thresholds defined by Landis & Koch (1977). Any discrepancies in coding were discussed and resolved through consensus to enhance coding accuracy and thematic alignment.

Results

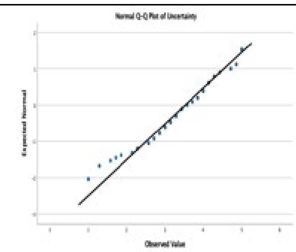
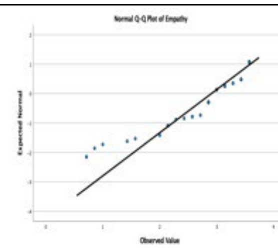
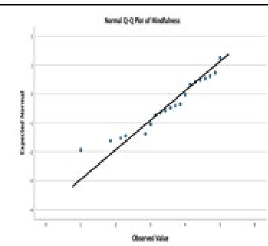
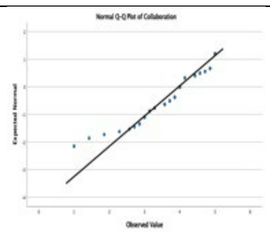
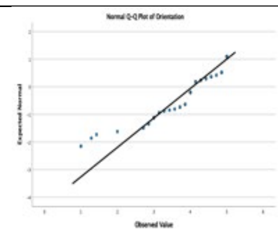
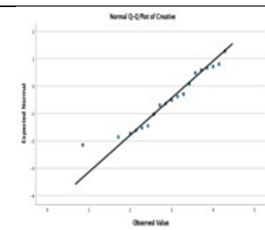
Survey Analysis

Preliminary Normality Test on a Subset of Participant

A preliminary normality test was conducted on a randomly selected subset of 20 participants from the full sample (n=94) to assess the distributional characteristics of the dataset before conducting a one-sample t-test. This subset was chosen to allow for an early diagnostic check before proceeding with inferential analysis, while preserving the integrity of the full dataset for the primary test. The Kolmogorov-Smirnov and Shapiro-Wilk tests indicated that five of the six DT mindset dimensions (uncertainty, empathy, mindfulness, collaboration, and orientation) followed a normal distribution. However, for "creative confidence," both tests yielded $p<0.05$, suggesting some deviation from normality. Despite this, it was determined that the normality assumption was sufficiently met to proceed with the t-test based on several factors. First, the sample size for the main analysis (n = 94) exceeds the threshold at which the t-test is generally considered robust to modest violations of normality, especially for Likert-scale data (Lumley et al., 2002). Second, a visual inspection of Q-Q plots for the full dataset revealed no extreme skewness or kurtosis for "creative confidence," supporting the assumption of approximate normality. Furthermore, the nature of the variable (a composite score based on multiple Likert-scale items) increases the likelihood of near-normality due to the central limit theorem. Based on this combination of statistical testing, visual inspection, and established guidelines, the one-sample t-test was considered an appropriate method for subsequent analysis.

The normality tests were performed using SPSS via q-q plot testing to visually inspect distributional patterns before conducting the one-sample t-test, following guidance from Field (2009). As illustrated in Table 1, most DT mindset variables (e.g., uncertainty, empathy, mindfulness, collaboration, and learning orientation) showed data points that closely aligned with the diagonal, indicating approximate normality. However, the Q-Q plot for "creative confidence" revealed more noticeable deviations from the expected line, suggesting potential non-normality. This finding is consistent with earlier statistical tests (Kolmogorov-Smirnov and Shapiro-Wilk) conducted on a subset of the data. Despite this deviation, the one-sample t-test was deemed appropriate for all variables, including "creative confidence," based on several considerations. First, the sample size (n = 94) exceeds the threshold at which t-tests are robust to moderate violations of normality (Lumley et al., 2002). Second, "creative confidence" is a composite score derived from multiple Likert-scale items, and the central limit theorem supports the assumption that such aggregate scores tend toward normality in larger samples. Therefore, the Q-Q plot results were interpreted in conjunction with sample size and scale structure, allowing the study to proceed with the t-test while maintaining statistical validity.

Table 1
Normality Tests of Sub-Factors and Total (Q-Q Plot Tests)

Uncertainty	Empathy	Mindfulness
		
Collaboration with others	Learning Oriented	Creative Confidence
		

One-Sample T-test

In this study, the TEALF served as the pedagogical intervention implemented before data collection. A one-sample t-test was conducted to determine whether the post-intervention mean scores for each DT mindset category significantly differed from the neutral midpoint of 3.0 on a 5-point Likert scale (Kent State University Libraries, 2017). While this test does not allow for causal inference or measurement of change over time, due to the absence of pre-intervention data, it does provide insight into whether preservice teachers' self-reported perceptions of their DT mindsets, following exposure to the TEALF, are significantly above a neutral reference point. The results indicated that all mean values across the six DT mindset categories were statistically higher than the neutral midpoint (See Table 2). As a result, the null hypothesis, which posited no significant difference between the observed sample mean set and the hypothesized population mean of 3.0, was rejected at the 95% confidence level. These findings suggest that, after participating in the TEALF, preservice teachers perceived themselves as demonstrating levels of DT mindset traits that exceed a neutral stance. However, no direct claims of growth or development can be made without a baseline comparison. The results showed that the mean scores for all six DT mindset categories were statistically significantly higher than the neutral midpoint of 3.0 ($p < .001$), indicating that preservice teachers rated their post-intervention perceptions of these traits as above neutral. Among the six categories, learning orientation had the highest mean score ($M = 4.05$, $SD = 0.938$), followed by collaboration ($M = 3.96$, $SD = 0.912$) and mindfulness ($M = 3.89$, $SD = 0.978$). These scores indicate relatively strong self-reported perceptions in these areas following engagement with the TEALF. Creative confidence, while the lowest mean increase (M = 3.32, SD = 0.738), was still significantly above the midpoint, with a moderate effect size (d = 0.73). The findings indicate that, following their perceptions in the TEALF, preservice teachers reported perceiving themselves as demonstrating levels of DT mindsets that exceed a neutral stance. However, due to the absence of pre-test data, these results should be interpreted as a snapshot of post-intervention perceptions, rather than evidence of change or growth over time. To better understand the relative strength of each DT mindset domain, the difference between each category's mean score and the scale midpoint (M = 3.0) was calculated. Orientation to learning exhibited the largest difference from the midpoint, exceeding it by 1.05 points. This was followed by collaboration (0.96), mindfulness(0.89), and uncertainty (0.52), suggesting higher perceived development in these areas. In contrast, the categories of empathy and creative confidence showed smaller differences, with values of 0.46 and 0.32, respectively, indicating more modest elevations above the neutral benchmark. These comparative differences reflect the varying degrees to which preservice teachers perceived alignment with each DT mindset domain after participating in the technology-enhanced active learning environment.

Table 2

Descriptive Statistics and One-Sample t-test

	Mean	**SD**	**t-value**	df	**p-value**	***d***	95% CI
Uncertainty	3.52	1.01	4.99	93	<.001	1.01	0.3-0.731
Empathy	3.46	0.81	5.52	93	<.001	0.81	0.3-0.628
Mindfulness	3.89	0.978	8.82	93	<.001	0.97	0.7-1.091
Collaboration	3.96	0.912	10.26	93	<.001	0.91	0.8-1.154
Learning Orientation	4.05	0.938	10.93	93	<.001	0.93	0.9-1.25
Creative Confidence	3.32	0.738	4.25	93	<.001	0.73	0.2-0.475

All six design thinking (DT) mindset categories yielded mean scores significantly above the proposed neutral midpoint (M = 3.0), indicating positive post-intervention perceptions. For the uncertainty, although one item, *I am comfortable dealing with unsolved problems*, did not reach statistical significance (p=0.155), the overall category mean was significantly higher (M=3.52, SD=1.01), t (93) = 4.99, p<.001, with a large effect size (d=1.01). This supports the overall strength of the uncertainty construct despite the isolated non-significant item. The empathy category also showed a significant result (M=3.46, SD=0.81), t (93) = 5.52, p<.001, d=.810, suggesting a moderate to large effect. Similarly, participants scored significantly above the midpoint in mindfulness (M=3.89, SD=0.978), t (93) = 8.82, p<.001, d=.97, and in collaboration (M=3.96, SD=0.912), t (93) = 10.26, p<.001, d=.91, both reflecting large effects. Orientation to learning recorded the highest mean among all categories (M=4.05, SD=0.938), t (93) = 10.93, p<.001, d=.93, highlighting a strong inclination toward active engagement with new knowledge. Finally, while creative confidence had the lowest mean (M=3.32, SD=0.738), it still exceeded the midpoint significantly, t (93) = 4.24, p<.001, d=.73, suggesting a moderate positive tendency. These results indicate that preservice teachers rated themselves above neutral across all DT mindset categories following their participation in the TEALF. These results reflect post-intervention perceptions, as they do not demonstrate a measurable change from the baseline or establish a causal impact.

Focus Group Discussion

The responses from the focus group discussion were analyzed using Braun and Clake's (2006) six-phase thematic analysis approach to identify patterns across participants' experiences. This iterative process involved data familiarization, generation of initial codes, theme searching, theme reviewing, theme definition, and reporting. Thematic categories were initially informed by Kolb's experiential reflection model, Description, Feelings, Evaluation, and Conclusion/Plans, which provided a structured lens for examining participants' learning journeys. These categories helped organize and interpret the data while remaining open to emergent DT mindset themes, including Uncertainty, Empathy, Mindfulness, Collaboration, Learning Orientation, and Creative Confidence.

For instance, in the description phase, many participants reflected positively on their use of technology within the DT process, though they also expressed feelings of initial cognitive overload. One participant described the experience as "overwhelming but transformative," highlighting the challenge of learning multiple new apps simultaneously. In the *feelings* category, most students reported initial discomfort and uncertainty but noted a growing sense of clarity and confidence in their teaching philosophy as the semester progressed. Regarding the *evaluation* category, students emphasized practical challenges, such as time management and choosing the right team, and shared that a few of their colleagues resisted the change. They also revealed increased confidence and appreciation for the flexibility that technology offers. Notably, participants connected their increased empathy for students' needs and mindfulness in lesson planning with their DT experiences. Finally, in *conclusion and action plans*, preservice teachers articulated their future goals and professional intentions, such as differentiating instruction, selecting tools purposefully, and cultivating student-centered learning environments. Table 3 presents a selection of representative participant quotes, organized by theme and experiential category, illustrating how these reflections align with and demonstrate development across the six core DT mindset constructs.

Table 3

Analysis of Coding Themes That Emerged from Participants' Responses

Theme	Initial codes	Subthemes	Participants' Quotes
Challenges in Adopting TEALF *(Descriptions)*	• Overwhelm • New tools • Digital learning curve	• Initial confusion • Cognitive overload • Adapting to new technologies	*At the beginning of the semester, we were overwhelmed with what we were learning. There were too many new applications to learn and apply. However, when we started working using these apps, we were very proud of what we achieved.* (**Student-1**) *Our instructor guided us to use the iCloud applications and earn badges to earn the Apple Teaching Certificate. In addition, we learned many other applications and understood how to be used in teaching, learning, and assessments.*(**Student-2**)
Transformation in DT Mindsets *(Feelings)*	• Growth, reframing • Self-awareness • Learner empathy	• Growth in uncertainty tolerance • Empathy • Mindfulness	*We were not feeling comfortable at the beginning of the semester as we were confused about the amount of information we received and how we will use all of these apps. However, later on, I noticed that I changed how I think of each application and how to use it in teaching and learning.***(Student-1)** *I feel that dealing with uncertainty was not easy to do; however, being empathetic about students' needs and creating activities to meet their needs is something I learned. Also, being aware of the process and purposes and having clear goals was added to me.*(**Student-3**) *The DT process was so confusing in the beginning….especially when we set checking points after each step to reflect and receive*

			feedback. We did not apply it properly in the first two challenges, but I believe we became experts later. (**Student-4**)
Collaboration and Knowledge Sharing *(Evaluations)*	• Peer support • Teamwork • Creative brainstorming	• Peer learning • Teamwork in designing STEM challenges	*To design an early-year STEM challenge and projects, we collaborated and used shared applications such as iCloud sheets, Google Docs, etc.* (**Student-3**) *I liked how we collaborated with our peers and came up with creative ideas. We feel confident that we can think of creative ideas whenever we start working on an idea. This motivated me to direct our process, learn more things, and be well-prepared for my future as a teacher.*(**Student-4**)
Creative Confidence Development *(Evaluations)*	• Experimentation • Learning through failure • Design iteration	• Iterative learning • Overcoming fear of failure	*Before, I hesitated to experiment with new teaching strategies, but now I feel more confident designing innovative learning experiences. The DT process showed me that failure is part of learning.* (**Student-1**) *There are some ways of learning we cannot forget as we learned something from. I benefit from using the DT process in my personal life….without being conscious, I found myself using the DT process to solve my problems to empathize, ask questions, plan and suggest solutions, evaluate my solutions, and improve when needed.*(**Student-3**)
Technology as an Essential Teaching Skill *(Evaluations)*	• Pedagogical tech use • Instructional flexibility • Confidence with tools	• Technology preparedness, flexibility in teaching	*Using technology applications in differentiating students' learning is beneficial. We used videos, audio, and sometimes writing to reflect on our work and give childhood learners feedback. It was easier to ensure that they understood the feedback by*

			sending them audios about their work…. Using different forms of presenting lessons in interactive ways makes students learn better. **(Student-1)** *I believe we learned a lot of essential skills for teachers. We were well prepared to use technology, especially in quarantine. We learned that there are no limits to learning, and the quarantine will not limit how we teach students.* (**Student-2**)
Technology as an Essential Teaching Skill *(Evaluations)*	• Technology preparedness • Flexibility in teaching • Overcoming resistance • Deeper understanding of pedagogy	• Overcoming initial resistance to change • Deeper understanding of pedagogy	*The only disadvantage I felt was that I was uncomfortable with this new learning environment where technology and DT are essential. It took time to understand and get used to that. However, it is beneficial and changed how I prepare and plan for STEM challenges and projects.* (**Student-2**) *During our study in this program, we learned a lot of theories and how beneficial they are; however, it is the first time we feel it as learners and think of how to create a Technology-Enhanced Active Learning Environment with young learners. I feel I can make a difference in students' lives.* (**Student-4**)
Recommendations for Future TEALF Implementation *(Conclusions and Plans)*	• Planning • Learner-centered strategies • Scaffolding • Reflective goals	• Students' needs • Need for gradual introduction • More structured feedback loops • Mindfulness	*I will consider my students' needs before planning and designing STEM challenges. I will differentiate the STEM challenges and projects that can meet their needs. I will also continue learning new applications and the purposes of using each application to ensure their effective use of them.* **(Student-1)**

			The first thing I will do is set a list of applications, their purposes, levels of using technology, etc., and then start the DT process. It is essential to ensure the effectiveness of technology applications used. (**Student-2**) *I will be mindful of my goals for myself, and for each goal, I will set mini-steps to be achieved. This will give me a better feeling about achieving my goals and keep me on track….. I realized how important mindfulness is, and I believe it is an essential skill to be taught for students in early years.* **(Student-3)** *I need to figure out more simple ways to teach early years students DT. It is vital for them not only for their cognitive development but also for their social, physical, and emotional development. So we teach a whole child who can cope in their lives not only to achieve high marks.* (**Student-4**)

Discussion

Q1: How Do Preservice Teachers Perceive Their Design Thinking Mindset After Engaging in a Technology-Enhanced Active Learning Environment in STEM Courses?

The DT mindset survey revealed that preservice teachers reported mean scores significantly above the neutral midpoint across all six mindset categories, suggesting a generally positive perception of their design thinking dispositions following the TEALF experience. While this post-intervention outcome indicates favorable self-assessments, it does not provide direct evidence of mindset development or transformation, given the absence of baseline (pre-test) data. Nevertheless, the findings offer preliminary support for the potential of integrating TEALF with DT processes in preservice teacher education, particularly within interdisciplinary STEM fields. This observation aligns with a previous study highlighting how innovative uses of technology may support the redefinition of teaching and learning experiences (Capone & Lepore, 2021).

The results indicated that empathy and creative confidence, while still scoring significantly above the neutral midpoint, exhibited the smallest mean differences among the six DT mindset categories. This suggests that participants' self-reported levels in these two areas were less pronounced compared to other mindset components such as learning orientation or collaboration. This pattern may reflect broader challenges in cultivating these particular traits within a short intervention period. For instance, Vignoli et al. (2023) emphasize that empathy requires deeper experiential engagement and sustained exposure to diverse perspectives, which may not be fully achieved through brief training formats. Similarly, Yilmaz-Soylu et al. (2021) highlight that creative confidence is often a cumulative outcome, developing over time as individuals repeatedly test ideas, receive feedback, and build resilience against failure. Therefore, the relatively smaller shifts observed in these areas are consistent with existing research, which positions empathy and creative confidence as traits that typically evolve more gradually within the DT framework. These findings suggest that while TEALF may foster initial positive orientations in these areas, more intensive or longitudinal interventions might be needed to produce stronger effects.

For *uncertainty*, the preservice teachers reported feeling generally comfortable with navigating unknown situations, embracing new contexts, and recognizing that solutions can emerge from unexpected directions**.** These attitudes are reflected in several survey items that received mean scores significantly above the neutral midpoint, particularly those addressing openness to ambiguity and adaptability in problem-solving. However, not all items within this category demonstrated strong alignment with a fully developed mindset of uncertainty. One item, *I feel comfortable dealing with unsolved problems,* did not reach statistical significance, suggesting lingering discomfort with situations where outcomes are undefined. This indicates a disagreement in their perceptions of uncertainty tolerance: While learners may welcome novel situations, they may still struggle when clarity is absent. Loderer & Kock (2021) noted that being comfortable with complex issues is used to explore all possibilities to consider a solution as an ill-structured and questionable concept. Similarly, Vignoli et al. (2023) suggest that the ambiguity inherent in the DT process, especially when both outcomes and timelines are uncertain, can provoke discomfort in learners unfamiliar with iterative, open-ended problem spaces. The findings here partially reflect this tension: Although preservice teachers demonstrated positive orientations toward ambiguity, full comfort with unresolved challenges may require deeper engagement or longer-term exposure. Thus, while the results suggest an emerging disposition aligned with the DT construct of uncertainty, they stop short of providing definitive evidence of its complete internalization. These interpretations are derived from the quantitative survey data. They should be considered in light of the study's post-test-only design, which cannot confirm developmental progression but can provide insight into post-intervention perceptions.

For *empathy*, preservice teachers reported efforts to understand the individual needs of early years students, often describing how they considered problems from the child's perspective when designing STEM challenges. These interpretations are drawn from the post-intervention survey responses related to the empathy dimension, where scores were significantly above the neutral midpoint. This empathetic stance aligns with the human-centered design approach, which emphasizes the ability to adopt multiple viewpoints and appreciate the motivations behind others' behaviors (Altay & Porter, 2021). Participants indicated that they sought to design challenges that reflected students' interests and aspirations, aiming to make a meaningful impact. They also associated empathy with maintaining a nonjudgmental mindset and feeling comfortable working with individuals from diverse backgrounds and perspectives, which reflects traits described by Noh and AbdulKarim (2021) as central to inclusive design practice. The TEALF intervention may have supported this empathetic orientation by immersing preservice teachers in iterative, learner-centered design tasks, where understanding students' needs was positioned as the starting point of the design process. Although these findings suggest that participants valued and attempted to apply empathy in their instructional design, the study's results indicate a positive self-reported disposition toward empathy following exposure to the TEALF environment. This insight contributes to the growing body of research linking TEALF with human-centered teaching practices in STEM education.

For *mindfulness*, survey responses suggested that participants valued open-mindedness and demonstrated an ability to stay focused on the problem-solving process. They reported an awareness of the need to redefine problems clearly and to explore alternative approaches without being hindered by fear of failure. Responses further indicated that participants recognized the importance of maintaining multiple possible solutions simultaneously and appreciated the iterative nature of the design process. Several noted an understanding of when to transition between divergent and convergent thinking phases, suggesting a growing process-oriented awareness. These findings align with Vignoli et al. (2023), who emphasized the importance of learners being mindful of the different stages of the design thinking process, including knowing when to engage in expansive idea generation versus targeted refinement. Although causality cannot be claimed due to the study's post-test-only design, the TEALF environment may have supported this awareness by embedding reflective checkpoints and structured opportunities for iterative work.

For *collaboration with others*, participants' survey responses suggested a strong preference for working in groups over working alone. They reported feeling comfortable collaborating with individuals from diverse backgrounds and valued learning from different perspectives. These responses were interpreted from the collaboration subscale of the DT mindset survey. Participants also indicated a willingness to engage in joint decision-making, share information openly, and co-construct new knowledge with peers. Such traits align with the collaborative competencies highlighted by Henriksen et al. (2022), who emphasized the importance of sharing knowledge and utilizing visualization tools to support group dialogue and meaning-making. Although visualization tools were not explicitly discussed in the current dataset, the TEALF intervention utilized collaborative digital platforms, such as shared iCloud sheets and Google Docs, which may have facilitated effective communication and content co-creation. Groeger and Schweitzer (2020) similarly stressed the value of multidisciplinary teamwork in fostering communication and broadening perspectives. The positive orientation toward collaboration observed in the survey responses suggests that the TEALF environment may have supported the perceived shift in mindsets.

Regarding *orientation to learning*, responses from the DT mindset survey indicated that participants valued experiential learning, reflection, and active engagement. They reported that they learn from their experiences, observations, and actions; apply newly acquired knowledge; incorporate feedback into their learning; and seek out unfamiliar information. They also described learning through discussion, sharing, and reflecting on their mistakes, as well as striving to gather as much relevant knowledge as possible. These behaviors align with the characteristics of design thinkers described by Vignoli et al. (2023), who emphasize the importance of challenging existing ideas and exploring new contexts. Similarly, Simeon et al. (2020) highlighted how such orientations support continuous learning and adaptability, qualities essential in design-driven fields. Although the study's quantitative design limits causal inference, it is possible that specific features of the TEALF intervention, such as iterative STEM challenge development and peer feedback mechanisms, contributed to the emergence of this active and self-directed learning mindset. The elevated mean score on the orientation-to-learning scale suggests that participants demonstrated a perceived shift in their mindset toward growth and learning after engaging in the TEALF-based activities, though further investigation using longitudinal or pre-post designs would be needed to confirm developmental change.

Finally, for *creative confidence*, results from the DT mindset survey indicated that preservice teachers reported the ability to propose ideas even with incomplete information, apply innovative thinking to solve complex problems, and generate novel ideas beyond existing solutions. They also noted the capacity to create models to represent new concepts, explore alternative possibilities, and derive value from outcomes to overcome challenges. These reported characteristics reflect key elements of creative confidence as described in the literature. Hamat et al. (2019) emphasize that the ability to think differently and to trust in one's capacity to solve problems innovatively signifies the development of creative confidence. Similarly, Henriksen et al. (2020) argue that creative confidence is a major contributor to effective problem-solving in design-oriented teams. While these results suggest a positive disposition toward creative confidence post-intervention, the study's quantitative methodology, specifically, the use of a one-sample t-test comparing scores to a neutral midpoint, limits the ability to claim definitive development. However, it is possible that components of the TEALF intervention, such as iterative STEM challenges, exposure to diverse digital tools, and scaffolded opportunities to experiment with instructional models, created an environment that encouraged risk-taking and creativity. This interpretation aligns with transformative learning theories (Capone & Lepore, 2021; Trust & Whalen, 2020), which highlight how immersive educational experiences can reshape learners' perspectives and promote deep shifts in mindset, especially when supported by reflective practice and active engagement.

Q2: What Are the Preservice Teachers' Perceptions of Using the Technology-Enhanced Active Learning Design Framework in STEM Courses?

The second question was addressed through the focus group discussion using four different aspects inspired by Kolb's experiential learning model: description, feelings, evaluation, conclusion, and plans, as a lens to analyze preservice teachers' perceptions. These perceptions were thematically analyzed using Braun and Clarke's six-phase approach, which helped interpret data from the DT dimensions.

In *Descriptive Perceptions*, the initial exposure to TEALF allowed preservice teachers to describe their experiences integrating technology with the DT process in a TEALF environment. Many expressed feeling overwhelmed at the beginning of the semester due to the steep learning curve associated with mastering multiple digital applications, earning the Apple Teaching Certificate, and understanding how to apply DT in their practice. Despite this, participants gradually developed familiarity with the tools and began to distinguish between applications used for teaching, assessment, and student engagement. This process of active engagement supported the activation of learners' prior knowledge, enabling them to encode new information more effectively within a virtual learning environment (VLE) (Hite et al., 2024). Such engagement provides insight into how technology can be used not only to deliver content but also to act as a driver of innovative, student-centered learning approaches (ElSayary et al., 2022). Preservice teachers described their experiences using technology with DT to create a TEALF, where they understood the differences between the applications used and how to use them in teaching, learning, and assessment. This is confirmed in a previous study by Chai et al. (2020), who highlighted the importance of providing teachers with the primary knowledge they need to plan technology-integrated lessons. Additionally, they described the DT process as confusing initially, but using it in planning STEM challenges and projects made them understand it very well. Similarly, a study by Tey et al. (2020) emphasized that STEM education marks a significant shift from traditional teaching methods, focusing on active learning where students engage in hands-on, practical problem-solving. This approach encourages a more profound understanding and suits the dynamic nature of 21st-century learners (Abykanova et al., 2016). They added that the tricky part was deciding when to create assessment checkpoints within the DT process to allow early-year students to reflect and receive feedback on their work. Capone & Lepore (2021) highlighted that the transformative approach integrates the content, pedagogy, and technology domains to support instructors in the teaching and learning process, which is challenging to achieve.

Regarding emotional reactions (*feelings*), preservice teachers felt overwhelmed at the beginning of the semester, as their learning environment was perceived as uncomfortable during the early stages of implementation. However, they recognized the value of learning and applying new approaches in teaching and learning through the DT process. This discomfort eventually facilitated growth, as learners developed a sense of competence and efficacy in using educational technologies. These emotional responses align with the principles of transformative learning theory, which posits that individuals can transform their perspectives and develop new skills and habits when confronted with challenging situations (Strange & Gibson, 2017). Abykanova et al.

(2016) and Capone & Lepore (2021) also stress that navigating such discomfort is a key catalyst for developing new habits of mind and pedagogical strategies. The key here is not only to know how to use new applications but also to understand when to use them and set them within teaching, learning, and assessment. Similar results were highlighted in a previous study where the efficient use of technology can empower teachers and students to build transferrable skills in a technology-enhanced active learning environment, such as computational thinking, creativity and innovation, critical thinking, self-direction, collaboration, and communication (ElSayary et al., 2022). In the present study, preservice teachers also appreciate collaborating with their teammates to create new ideas. They mentioned that each has different interests, strengths, and weaknesses, and they benefit from their differences. The same results were noted in a previous study, which stated that learners' collaboration helps establish a friendly learning environment among them, allowing for open communication (Rybakova et al., 2021). This study contributes to the body of knowledge surrounding the TPACK framework by exploring the implementation of technology, content, and pedagogy in a technology-enhanced active learning environment. It offers a unique perspective on how this framework can be applied in preservice teacher education (Hirsh & Baronak, 2020), where preservice teachers expressed that they became advanced technology users.

In *evaluating* the technology-enhanced active learning environment, participants offered critical reflections on the benefits and limitations of TEALF. A frequently cited challenge was identifying the optimal timing for formative assessment check-points within the DT process, particularly when working with early years learners. Participants noted that, although the DT process was initially unclear, experiential engagement helped them understand when and how to utilize it. They highlighted how technology enabled differentiation by allowing multiple modes of feedback, including audio, video, and written formats. They considered themselves in the students' place and tried to think about how to meet their different individual needs. They shared some ideas, such as recording the feedback using audio, videos, and sometimes writing. They added that they could differentiate the learning environment using interactive technology, where students act as active rather than passive learners. ElSayary et al. (2022) stated that providing a technology-enhanced active learning environment that supports students' development, meets individual needs, and designs a thinking mindset is essential. In the present study, preservice teachers demonstrated familiarity with the DT process to the extent that they reported applying it intuitively when solving problems, suggesting a perceived shift in their DT mindsets. Previous studies mentioned that teachers and students should be involved in the analysis, design, development, and evaluation process when using technology, as it leads learners to a perceived shift in their DT mindsets needed to prepare them for future jobs (Scanlon et al., 2019).

In reflecting on their *plans*, learners stated some essential actions they would consider. For instance, they mentioned using TEALF and DT to differentiate the learning environment to meet all students' needs. They also noted that they need to list the technology applications, purposes, and the level of thinking required to design a technology-enhanced active learning environment that effectively utilizes technology. They expressed a desire to create technology-enhanced active learning environments that support not only academic but also social, emotional, and cognitive development. In addition, they mentioned the importance of developing mindfulness skills in students from an early age due to the positive impact it has on their social, emotional, physical, and cognitive development. These reflections align with previous studies highlighted the importance of developing mindfulness, stating that learners build up creative confidence and become innovative when they are mindful of their learning process as learners who can use information, act as researchers, solve complex problems, empathize with individuals' needs and create new products that meet their needs (Abykanova et al., 2016). Furthermore, preservice teachers believed that they could integrate the content, pedagogical, and technological knowledge, aligning with the goals of the TPACK framework (Capone & Lepore, 2021; Gess-Newsom, 1999). The focus group data reveal how preservice teachers' engagement with TEALF impacted their instructional perspectives in the DT mindset across all of Kolb's reflective stages. Their perceptions were closely tied to experiential learning, peer collaboration, and exposure to innovative technology. This confluence supports a shift toward more adaptive, empathetic, and creative teaching practices in STEM contexts. This study's contribution lies in its holistic approach to integrating technology and DT in teacher education, its insights into transformative learning processes, and its practical implications for enhancing the pedagogical skills of future educators, as mentioned in previous studies (Hsu & Tsai, 2022; Zuhaida et al., 2022). These findings can inform future research, policy-making, and practice in educational technology and teacher education.

Conclusion and Recommendations

This study explored how preservice teachers perceived their DT mindsets after participating in a TEALF within interdisciplinary STEM courses. Post-intervention survey results showed that participants reported DT mindset scores significantly higher than the neutral midpoint across all six mindset dimensions: uncertainty, empathy, mindfulness, collaboration, orientation to learning, and creative confidence, indicating a generally positive disposition following their experience with TEALF. These findings suggest that the framework may support the cultivation of DT traits when implemented with digital tools and scaffolded experiential learning, although the study design does not allow for causal conclusions. Participants engaged with a variety of interactive digital applications and completed an intensive training period that included earning the Apple Teaching Certificate. While these components may have contributed to the observed positive perceptions, direct attribution of mindset outcomes to specific intervention features should be made cautiously. Notably, one aspect of uncertainty (comfort with unsolved problems) did not change significantly; it was still encompassed within the broader positive shift. This item was neglected as the overall result of uncertainty showed a considerable difference. Mezirow (1997) notes that transformation in habits of mind can require reflective thinking, which may explain this challenge with some aspects of uncertainty.

Preservice teachers initially reported feelings of discomfort and confusion during their two-week training period, particularly due to the intensity of mastering new technologies and understanding the DT process. These reactions emerged clearly in the focus group discussions, where participants described the early learning environment as overwhelming yet necessary for growth. However, after applying the DT process, they recognized the benefits of what they had learned. This aligns with Strange and Gibson (2017), who found that perspective shifts often occur in response to uncomfortable situations. Such shifts are key features of transformative learning, wherein individuals reframe their prior assumptions through critical reflection and experiential engagement. In this study, the experience of navigating uncertainty, applying iterative thinking, and collaborating with peers likely served as catalysts for such transformation.

The participants' recognition of these benefits, expressed in their reflections on future teaching practices and their increased confidence, suggests that the initial cognitive dissonance played a productive role in shaping their DT mindsets.

Based on the study's findings, it is recommended that preservice teachers' education programs continue to emphasize the development of technological pedagogical content knowledge, with a particular focus on the DT process. Focus group results highlighted that preservice teachers valued the opportunity to use technology creatively and collaboratively to design meaningful STEM learning experiences. They reported that engaging with the DT process enhanced their ability to navigate ambiguity, generate innovative ideas, and reflect critically on their pedagogical practices, core competencies aligned with the TPACK framework.

Additionally, several participants highlighted how mindfulness, both in managing their own learning goals and in empathizing with students, was essential to their growth as future educators. This suggests that embedding structured mindfulness activities and elements of positive education should be considered for inclusion in teacher education programs, which could further support emotional well-being, self-regulation, and reflective practice. Such strategies may be particularly beneficial in cultivating resilience and purpose in teaching from early years through secondary education, aligning with broader goals for social-emotional learning and sustainable professional development across K–16 settings.

Future research should build upon the current study by addressing both its methodological constraints and the conceptual insights it has generated. While the survey revealed that preservice teachers exhibited DT mindset scores above a neutral midpoint following their participation in the TEALF, the post-test-only design limited the ability to assess change or causality. To more robustly examine the development of DT mindsets over time, future studies should adopt longitudinal or pre-post designs, allowing for direct comparisons and stronger causal inferences. Additionally, although the findings suggest a possible link between Design Thinking and personal growth areas, such as mindfulness and empathy, the role of positive education in supporting DT mindset development and enhancing student well-being remains underexplored. Investigating this relationship could uncover synergies between emotional well-being and creative, collaborative problem-solving.

This study's sample, comprised exclusively of female preservice teachers in an early childhood education program at a federal university in the UAE, also limits the generalizability of the findings. Future research should aim to include more diverse populations across gender, academic level (e.g., K–12 teacher preparation), and cultural contexts to validate and extend the applicability of TEALF. In addition, the suggestion to analyze preservice teachers' weekly reflections stems from the recognition that self-reported survey responses may not fully capture the evolving, detailed nature of mindset development. Incorporating longitudinal qualitative data, such as reflective journals or learning portfolios, could offer deeper insights into how individual perspectives and competencies shift throughout training. Finally, this study also encountered limitations related to the use of a one-sample t-test and the interpretation of mean scores against a neutral benchmark. While this provided an initial indication of positive disposition post-intervention, it does not substitute for direct evidence of learning gains. Future research should employ more rigorous statistical models and ensure that theoretical constructs are consistently defined and cited, thereby avoiding reliance on placeholder references. Addressing these methodological limitations will not only strengthen the evidence base but also enhance the practical utility of TEALF in shaping resilient, reflective, and innovative educators in STEM education and beyond.

Declarations

Conflicts of Interest

Author certifies that she has no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Data Availability

All relevant data, material and coding is included in the manuscript.

Ethics Statement

The study was approved by the Researcher University's Ethics Committee with approval no. ZU21_148_F

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