When Teacher Educator Use Design Thinking (DT) to Design Learning Experiences for Mathematics Student Teacher

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Abstract

This article aims to explore how to use Design Thinking (DT) to create a learning experience that promotes the development of TPACK among mathematics student teachers, specifically those enrolled in the courses Digital Technologies for Mathematics Learning Management (EM23201) and Media Construction for Mathematics (EM23301) at the Faculty of Education, Udon Thani Rajabhat University.

Research was conducted on the concept of self-study; data was gathered from a variety of sources to ensure data triangulation. During the 2023 academic year. The research findings revealed that the method of utilizing Design Thinking (DT) in the design of learning experiences led to the improvement of TPACK for mathematics student teachers. This approach encompassed the stages; (1) Empathize: understanding the specific TPACK needs and challenges of mathematics student teachers, (2) Define and Ideate: create a problem statement that succinctly captures the learning need or challenge and generates potential solutions, (3) Prototype and Test: creating prototypes of learning solutions integrate technology into mathematics teaching, and observe student teachers learning when implement the prototypes in real teaching scenarios, (4) Iterate and Improve: refine the technology-integrated teaching methods and learning experience, and (5) Reflect and Self-Study: Teacher educators engage in self-study, reflecting on their own teaching practices.

The outcomes of this research indicate that learning experiences designed through the using of DT not only deepen the understanding of mathematical concepts for mathematics student teachers but also equip them with the competence to effectively integrate technology into their teaching methods. This research provides valuable insights into the potential of design thinking and self-study as tools for teacher professional development and the enhancement of TPACK in mathematics education.

Keywords: self-study, Design Thinking, Technological, Pedagogical, and Content Knowledge (TPACK)

Introduction

In an increasingly globalized world, mathematical literacy is essential for staying competitive in various industries and for solving global challenges, such as climate change and healthcare. Mathematics helps students develop critical thinking and problem-solving skills. It teaches them how to analyze complex situations, break them down into manageable parts, and find solutions, which are essential life skills. (Kilpatrick, Swafford, and Findell, (Eds.), 2001)

According to a study by the World Economic Forum (2023), analytical thinking and creative thinking are the second core skills for its workers in 2023 versus the probability of the skill appearing in its reskilling and upskilling initiative in the next five years. This underscores the significance of incorporating design thinking in education to foster creative problem-solving abilities among students. Design thinking empowers students to approach challenges with innovative solutions, aligning with the evolving demands of the future job market.

However, in numerous Mathematics Bachelor of Education programs, the mathematical content presented tends to be highly abstract, posing substantial challenges for teacher educators seeking to employ active learning methods and offer students greater opportunities for self-directed engagement in mathematical concept formation. These challenges are underscored by the feedback provided by student teachers, which consistently highlights deficiencies in instructional clarity. Student teachers often attribute their difficulties in achieving a comprehensive understanding of mathematical concepts to a pedagogical approach characterized by didactic lectures. Consequently, the prevailing outcome is an inclination among student teachers to rely on rote memorization of mathematical formulae and concepts, with limited emphasis on genuine comprehension. Moreover, student teachers frequently adopt a mimetic learning approach, wherein they emulate predefined models. These collective factors ultimately impede student teachers from effectively applying mathematical knowledge to solve real-world problems autonomously.

Research findings indicate that a prominent challenge in the preparation of student teachers or pre-service educators lies in their ability to formulate effective instructional strategies. Pre-service teachers often encounter difficulties in crafting instruction that aligns with the diverse needs of their students. The data further highlights a deficiency in appropriate learning materials for pre-service educators and time constraints that hinder their capacity to engage students effectively in achieving learning objectives which revealed that many pre-service teachers grapple with the complexities of instructional design, lesson plan development, and the motivation of students to actively participate in the learning process. (Brown and Melear, 2007; Chaichaowarat R., 2018)

This phenomenon underscores the pressing need for reform in mathematics education, focusing on rendering mathematical content more accessible, fostering pedagogical approaches that encourage active learning and critical thinking, and empowering student teachers to transcend mere formulaic understanding in favor of deeper mathematical insight.

Design Thinking is an academic discipline rooted in the utilization of the designer's cognitive framework, perceptiveness, and methodologies to address the requests of end-users with the objective of formulating a strategic plan that is concurrently technologically executable and commercially advantageous. This process is designed to translate these strategies into customer value and capitalize on market prospects (Brown, 2008). Within the sphere of education, Design Thinking assumes a pivotal role by cultivating the potential to prepare students for the dynamic and evolving demands of the future.

In this context, an intriguing query emerges: How can Teacher Educator specializing in mathematics effectively assimilate Design Thinking (DT) process into the designing of the learning experience, thereby equipping student teachers with the essential amalgamation of Technological, Pedagogical, and Content knowledge (TPACK), and fostering their capacity for innovative problem-solving? These competencies are integral not only for the prospective educators themselves but also for the skill development of their future students, aligning them with the requirements of the workforce that lies ahead.

In light of the challenges and scenarios presented, as educators with a vested role in the instruction of the courses "Digital Technologies for Mathematics Learning Management (EM23201)" and "Media Construction for Mathematics (EM23301)," our objective is to cultivate enriched learning experiences within both courses. To this end, we have opted to employ a self-study research methodology. Self-study is chosen as a research approach, as it confers the capacity for teacher educators to proactively advance their professional acumen. Through active involvement in research endeavors and the cultivation of reflective practices, teacher educators can foster a continuous trajectory of professional development, allowing them to not only embrace but also adapt to the dynamic milieu that characterizes contemporary education (Vanassche and Berry, 2020; Craig and Curtis, 2020).

Research Objective

The primary objective of this research endeavor was to design a learning experience that fosters the enhancement of the Technological, Pedagogical, and Content Knowledge (TPACK) of mathematics student teachers enrolled in the courses "Digital Technologies for Mathematics Learning Management (EM23201)" and "Media Construction for Mathematics (EM23301)" at Udon Thani Rajabhat University.

Literature Review

This study aims to develop learning experiences of the courses "Digital Technologies for Mathematics Learning Management (EM23201)" and "Media Construction for Mathematics (EM23301)" at Udon Thani Rajabhat University that foster the enhancement of mathematics student teachers' TPACK. The research landscape encompassed pertinent academic literature and studies, encompassing concepts of self-study, Design Thinking, and the TPACK framework.

1. self-study

Self-study research, referred to as self-study in the realms of teaching and teacher education, entails a structured investigative method enabling educators, encompassing both teachers and teacher educators, to scrutinize and contemplate their professional practices. This methodology aligns with the principles of action research, where individuals embark on a continuous journey of introspection and enhancement within their educational capacities.

To advance comprehension, self-study research should transcend individual introspection, demonstrating the processes by which personal beliefs are questioned and transformed. Moreover, these revelations should be shared with the larger community of teacher educators (Bullough & Pinnegar, 2001; Loughran, 2007). An overarching objective of self-study is to shed light on matters within teacher education (Bullough & Pinnegar, 2001).

Self-study researchers carry a personal obligation to reflect on their professional practices (Russell, 1998). According to Feldman, Paugh, and Mills (2004), self-study embodies three key elements: the centrality of self, the utilization of teacher educators' experiences as research, and a discerning self-examination of the researcher's methods. This study builds upon prior research conducted by Berry (2007) inquiring, 'How do teacher educators enhance their understanding of teaching teachers?'

In this research, our emphasis was on exploring the teaching and learning aspects of two courses: 'Digital Technologies for Mathematics Learning Management (EM23201) and Media Construction for Mathematics (EM23301). Our primary objective was to gain insights into the effective preparation of mathematics student teachers with TPACK.

2. Design Thinking (DT)

After studying and analyzing literature about DT from Brown (2008); Fischer (2015); Dunne and Martin (2006); Johansson-Skoldberg and Wodilla (2013); Donar (2011) and Schlenker and Chantelot (2014), an encapsulation of the salient aspects of design thinking is presented as follows.

Design thinking, abbreviated as DT, emerged as a problem-solving approach in the 1960s and has recently gained widespread popularity. While its origins lie in the realm of design, it has since found applications in diverse fields, including business, healthcare, and education. The foundations of design thinking can be attributed to influential design theorists and practitioners such as Buckminster Fuller, Christopher Alexander, and Horst Rittel. They stressed the significance of human-centered design, which involves understanding user needs, generating ideas, prototyping, and testing. Design thinking, commonly utilized in product design, has expanded its reach to areas such as educational design.

The evolution of design thinking can be linked to the efforts of design educators and researchers associated with institutions like the Bauhaus in Germany and the Royal College of Art in London. In the 1980s, design thinking gained prominence through the contributions of the

design firm IDEO and its founder, David Kelley. Kelley further established the Hasso Plattner Institute of Design at Stanford University, known as the d.school.

Design Thinking is a methodology that leverages the mindset, sensibility, and techniques of designers to meet the needs of end-users. This approach aims to create strategies that are both technologically viable and business-savvy, ultimately leading to the delivery of value to customers and seizing market opportunities. In essence, design thinking employs the sensibilities and methodologies typically employed by designers to innovate, provide solutions, explore alternatives, and address the desires of end-users or stakeholders. It is fundamentally characterized by abductive thinking, requiring individuals to break free from conventional solutions in favor of creative problem-solving.

Design Thinking characterized as a dynamic and non-linear framework by Scheer et al. (2011), encompasses an iterative process comprised of five key stages: (1) Empathize, (2) Define, (3) Ideate, (4) Prototype, and (5) Test. Carroll, Goldman, Britos, et al (2010) provide a concise interpretation of design thinking, particularly in the context of education. They describe it as an educational approach that prioritizes the cultivation of students' creative confidence. This approach involves active participation in hands-on design challenges with an emphasis on nurturing empathy, instilling a bias towards taking action, promoting idea generation, fostering metacognitive awareness, and facilitating creative problem-solving.

In the context of applying Design Thinking in educational settings, it primarily manifests in two ways: 1) the methodology of teaching and learning, and 2) the design of curricula and learning experiences. In our research, we employ Design Thinking to shape the learning experiences within two of our courses, aimed at enriching the Technological Pedagogical Content Knowledge (TPACK) of mathematics student teachers.

3. TPACK: Technological, Pedagogical, and Content Knowledge

TPACK, an acronym for "Technological Pedagogical Content Knowledge," represents a theoretical framework created to delineate the amalgamation of knowledge essential for educators. It elucidates the multifaceted knowledge that teachers require not only to instruct their students in a particular subject but also to do so effectively, while proficiently integrating technology into the teaching and learning process.

The TPACK model was written in 2006 by Mishra and Koehler in “Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge.” They explain that TPACK expands upon PCK which focuses on the knowledge and understanding that teachers have about how to teach a specific subject or content area effectively. It involves the blending of pedagogical knowledge (how to teach) and content knowledge (what to teach), by incorporating the effective use of technology in teaching. It recognizes that modern education often requires the integration of technology tools and resources.

TPACK highlights the intersection of three primary knowledge domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). It emphasizes how

teachers should seamlessly integrate technology into their pedagogical approaches while maintaining a deep understanding of the subject matter and encourages educators to consider how technology can enhance learning, engage students, and facilitate the delivery of content.

The development from PCK to TPACK signifies an evolution in teaching practices to embrace the opportunities and challenges presented by technology in education. It underscores the importance of educators possessing the skills and knowledge to effectively merge technology, pedagogy, and content to provide high-quality learning experiences for students.

Presently, there exists a disconnect between technology and the educational process. Often, during Professional Development workshops, educators receive training on specific software or applications, but the crucial aspect of integrating this technology effectively into the classroom is often overlooked. Mishra and Koehler's perspective underscores the need for educators to develop TPACK, which integrates technology seamlessly into pedagogical approaches while focusing on the content and the best ways to engage and educate students.

Conceptual Framework

This research is a research study that aims to develop learning experiences that foster the enhancement of mathematics student teachers' TPACK. Researchers define the research conceptual framework based on the concept of self-study research and Design Thinking together with TPACK.

The conceptual Framework as follows;

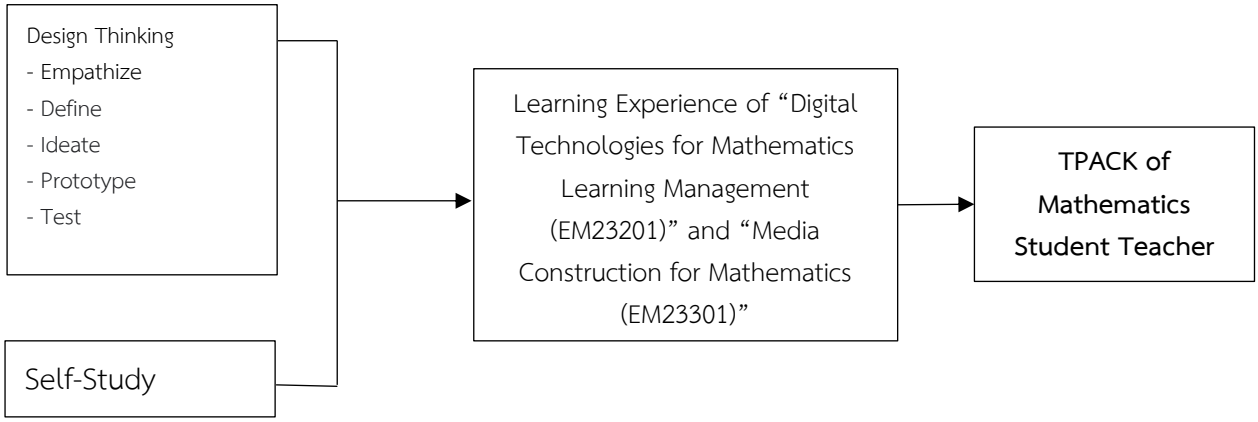

Fig. 1 Conceptual Framework.

Research Methodology

The focus of this study was our teaching and the way we conducted ourselves in the courses "Digital Technologies for Mathematics Learning Management (EM23201)" and "Media Construction for Mathematics (EM23301)" at Udon Thani Rajabhat University. As such, it necessitated a self-study through research and development because self-study as a research

design allows teacher educators to reflect on their own perceptions of practice and further their development as teacher educators (Loughran, 2007; Zeichner, 2007).

In this study, we wanted to know how we could best operate the learning experience to our mathematics student teacher. It was apparent to us that we could not teach them with the traditional approach and were waiting to confront problems of mathematics student teachers' learning achievement.

Without directly tackling our students' TPACK concerns, how can we consolidate our core values as teacher educators? We embarked on our journey with student teachers, keeping this question at the forefront of our approach. These aspiring student teachers sought to become well-versed in TPACK, which frequently translated into acquiring the strategies they would employ in the future and understanding the methods they should employ for effective teaching.

Data was gathered from a variety of sources to ensure data triangulation. During the 2023 academic year, qualitative data was collected through a series of initial observations in four classes of student teachers enrolled in two of our research courses. The data collection focused on our design and learning experiences, with the primary sources of data encompassing:

1. Entries from our professional journal logs, dating back to the academic year 2022 and earlier, which provided insights into my experiences as a course instructor.

2. Formal analytical reflections written after teaching, sharing, and discussions with student teachers, as well as our colleagues.

3. Analytical reflections from our student teachers during the first semester of the 2023 academic year.

To complement these data sources and ensure triangulation, we conducted informal interviews with our student teachers after their classes. These interviews, lasting at least one hour, centered on discussions about their approaches to material development and innovation, their learning experiences, suggestions for enhancing material and innovation, and the challenges they encountered in both courses.

Research Results

Based on a comprehensive analysis of reflections within our class, these reflections encompass the feedback provided by mathematics student teachers following the completion of our semester. Additionally, reflections were shared during informal meetings with colleagues, where we collectively discussed our learning experiences within the class. Furthermore, our reflections, which involved both ourselves and our student teachers, were rooted in the learning experiences developed during the courses "Digital Technologies for Mathematics Learning Management (EM23201)" and "Media Construction for Mathematics (EM23301)." These courses were conducted in the first semester of the 2023 academic year.

We have also discovered a method of utilizing Design Thinking (DT) in the designing of learning experiences that facilitate the improvement of Technological, Pedagogical, and Content Knowledge (TPACK) for mathematics student teachers, as outlined below:

1. Empathize: Teacher educators should start by understanding the specific TPACK needs and challenges of mathematics student teachers. This empathetic approach helps identify the areas where technology integration is most needed. For example, during an interview, Teacher educators might ask a student teacher to describe their experience with a particular subject or assignment. Teacher educators could then practice active listening by maintaining eye contact, focusing on the student's words, and paraphrasing their responses. They might also ask open-ended questions like, "Can you tell me more about what you found challenging about that assignment?" to encourage the student to share additional insights.

2. Define and Ideate: Teacher educators should begin by defining the specific objectives of the learning experience for mathematics student teachers and then identify their strengths and weaknesses in TPACK components. Once the problem has been defined, the teacher can then create a problem statement that succinctly captures the learning need or challenge. A good problem statement should be focused, specific, and measurable, and should clearly articulate the intended learning outcome. For example, "Student teachers need a way to make connections between what they are learning in the classroom and how it can be applied in real-world scenarios." Once the problem has been clearly defined, the next step is to generate potential solutions. This may involve brainstorming sessions, idea-generation activities, and other techniques to generate a wide range of potential solutions.

3. Prototype and Test: Teacher educators creating prototypes of learning solutions integrate technology into mathematics teaching by using the Learning Design Canvas, Paper prototyping, and Digital prototyping such as Desmos, GeoGebra and then implement the prototypes in real teaching scenarios. Observe how student teachers interact with the technology. Collect feedback to understand what works and what needs improvement.

4. Iterate and Improve: Based on feedback and outcomes, refine the technology-integrated teaching methods and learning experience. Encourage student teachers to reflect on their experiences and suggest improvements, fostering a culture of continuous improvement.

5. Reflect and Self-Study: Teacher educators should also engage in self-study, reflecting on their teaching practices and how they facilitate TPACK development in student teachers. They can refine their instructional strategies to better support TPACK growth.

By combining design thinking principles in learning experience design, teacher educators create a dynamic and responsive approach to enhance TPACK for mathematics student teachers. This process allows for personalized support, iterative improvement, and the development of effective technology-integrated teaching practices.

Discussions

Design thinking proves highly effective in educational design by fostering a student-centered, problem-solving approach. It emphasizes empathy, ideation, and prototyping, empowering educators to create engaging and pertinent learning experiences (Brown, 2008; Meinel, Leifer, and Plattner, 2011; Kolko, 2015).

In the practical application of the design thinking process (DT) to shape learning experiences through processes; Empathize, Define and Ideate, Prototype and Test, Iterate and Improve, and Reflect and Self-Study, it becomes evident that mathematics student teachers not only deepen their understanding of mathematical concepts but also develop the competence to seamlessly integrate technology into their teaching methods. Brown (2008) describes how this process fosters collaboration, encourages innovation, and tailors instruction to meet diverse learners' needs. The iterative nature of design thinking allows continual enhancement and adaptation to evolving educational contexts.

Concurrently, self-study in teacher professional development has been proven effective in elevating educators' knowledge and teaching practices. It empowers educators to take charge of their learning and customize it to their specific requirements. This self-directed approach cultivates reflective teaching, encourages ongoing improvement, and instills a sense of empowerment in teachers. Research has demonstrated that self-study leads to improved classroom instruction, better student outcomes, and heightened job satisfaction among educators (Wei, Darling-Hammond, Andree, Richardson, and Orphanos, 2009; Ingersoll and Strong, 2011; McLaughlin and Talbert, 2006).

Conclusion

The outcomes of this research indicate that learning experiences designed through the use of DT not only deepen the understanding of mathematical concepts for mathematics student teachers but also equip them with the competence to effectively integrate technology into their teaching methods. This research provides valuable insights into the potential of design thinking and self-study as tools for teacher professional development and the enhancement of TPACK in mathematics education.

Suggestions

As a result, learning experiences designed through the application of DT yield two key outcomes:

1. Engaging learning experiences provide mathematics student teachers with opportunities to actively construct their understanding. They learn not just by doing but also through sharing and reflecting with their peers. In the context of mathematical knowledge aligned with the curriculum, these student teachers can independently grasp fundamental concepts, thanks to the solid foundation they have previously established.

2. They facilitate collaborative work among mathematics student teachers to analyze diverse learning contexts, nurturing an understanding of classroom challenges in mathematics and promoting problem-solving using both digital technology and traditional materials. Ultimately, this approach equips them with the skills to seamlessly integrate technology into mathematics classrooms.

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