Student Teachers as Game Designers: Applying Design Thinking in Educational Tabletop Games Development

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ABSTRACT

Educational tabletop games offer significant pedagogical advantages due to their tangible, collaborative nature and minimal technological requirements, positioning them as valuable tools for diverse educational settings. While Design Thinking, a systematic framework encompassing empathizing, defining, ideating, prototyping, and testing, is recognized for fostering 21st-century competencies and empowering educators, its application to non-digital tabletop game design remains underexplored. This study investigated how student teachers applied the five phases of Design Thinking in developing tabletop games for instructional use. Employing an exploratory qualitative case study, the research discovered six groups of student teachers from a Malaysian public university, gathering data through participant observations, focus group discussions, cultural probes via weekly e-portfolios and document analysis. Findings revealed a systematic and effective adoption across all Design Thinking phases: participants adeptly used Empathize to identify authentic learning challenges, synthesized findings into actionable problem statements during Define, blended pedagogical knowledge with creative game design in Ideate, facilitated rapid iteration in Prototyping, and recursively refined their games through Testing, significantly enhancing both educational effectiveness and playability. This research highlights Design Thinking's flexibility in non-digital educational contexts, offering practical insights for developing game design competencies in future educators and enhancing teacher development programs.

Keywords: Design Thinking, Educational Tabletop Games, Student Teachers, Game Development

INTRODUCTION

Game based learning has received growing attention for its ability to combine engagement with meaningful learning outcomes. While much of the existing research focuses on digital game environments, educational tabletop games offer distinctive advantages that are particularly relevant for diverse classrooms. Their tangible format, collaborative nature, and low resource requirements make them suitable for contexts where digital infrastructure is limited or where hands on, social interaction is pedagogically desirable (Agbo et al., 2023; Engelstein and Shalev, 2022; Martin et al., 2021). These characteristics align with experiential learning principles that value active participation, concrete problem solving, and authentic interaction (Hsieh et al., 2023; Boller and Kapp, 2017). Despite these advantages, research on tabletop games as instructional tools remains comparatively limited, especially with regard to understanding how such games are designed rather than how they perform as final products.

Design Thinking provides a structured and iterative framework that supports innovation in educational design (as shown in Figure 1). Its phases of empathizing, defining, ideating, prototyping, and testing offer a systematic approach to developing solutions grounded in user needs (Stanford d.school, 2018; Brown, 2019). Within teacher education, Design Thinking has gained attention for helping educators cultivate competencies such as creativity, reflective problem solving, and learner centred decision making (Kim, 2022; Wasyluk and Kucner, 2021; Panke, 2020). However, most existing studies focus on digital game development or evaluate the effectiveness of completed games rather than examining how student teachers actually engage in the design process. This limit understanding of how Design Thinking functions as a learning experience within teacher preparation, and how student teachers internalise its principles during the creation of instructional materials.

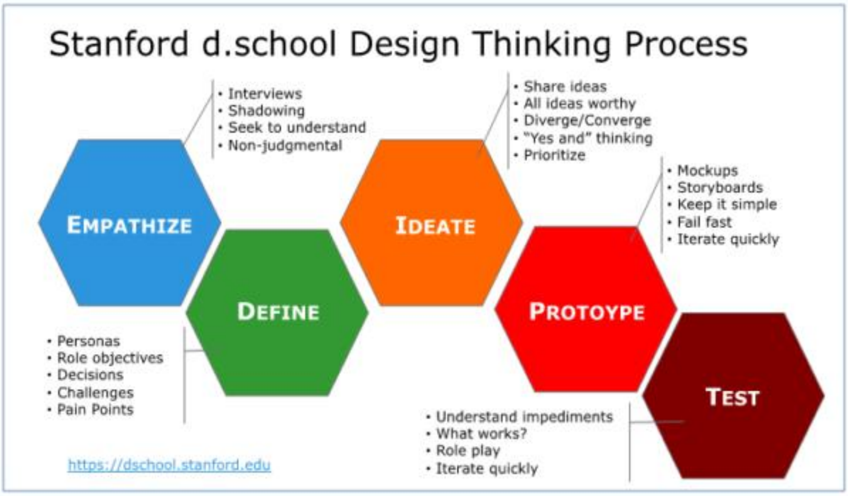

Figure 1: The Stanford d.school design thinking model (Stanford d.school, 2018)

Design Thinking provides a structured and iterative framework that supports innovation in educational design. Its phases of empathizing, defining, ideating, prototyping, and testing offer a systematic approach to developing solutions grounded in user needs (Stanford d.school, 2018; Brown, 2019). Within teacher education, Design Thinking has gained attention for helping educators cultivate competencies such as creativity, reflective problem solving, and learner-centred decision making (Kim, 2022; Wasyluk and Kucner, 2021; Panke, 2020). However, existing studies focus on digital game development or evaluate the effectiveness of completed games rather than examining how student teachers engage in the design process. This limit understanding of how Design Thinking functions as a learning experience within teacher preparation, and how student teachers internalise its principles during the creation of instructional materials.

This study seeks to extend the existing body of research by examining Design Thinking as it unfolds within the context of non-digital tabletop game development. While prior studies tend to describe Design Thinking conceptually or emphasise its outcomes, this study focuses on how student teachers enact its phases in real time. Through this process-oriented lens, the study introduces and illustrates the emerging idea of pedagogical design thinking, an approach through which student teachers balance learner needs, curriculum requirements, and engagement strategies while iteratively refining instructional resources. Documenting this process offers important insights that have been underrepresented in previous work, which has often prioritised end products or digital formats.

This focus is especially relevant in teacher education, where student teachers must learn to interpret learner needs, design instructional materials, and make informed pedagogical decisions before entering the profession. Prior research involving experienced teachers (Kim, 2023; Bressler and Annetta, 2022; Noh and Karim, 2021) and students (Hua et al., 2023; Bulut et al., 2022) has demonstrated the value of Design Thinking, but little is known about how student teachers navigate its phases when developing instructional media. Understanding their design processes can help teacher education programmes better support the development of design capacity, reflective thinking, and user centred pedagogy.

Therefore, this study aims to explore how student teachers apply the five phases of Design Thinking when developing educational tabletop games intended for instructional use. Guided by this aim, the central research question is as follows: How do student teachers adopt the five phases of Design Thinking in developing educational tabletop games?

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METHOD

Research Design

This study adopts a qualitative research approach, employing a case study design to investigate how student teachers enacted Design Thinking during the development of educational tabletop games. Research design provides the overall framework that systematically links the research questions, context, data sources, and analytical procedures (Creswell & Poth, 2018; Yin, 2018). In this study, the design structured the examination of a Design Thinking–integrated game development task embedded within a 14-week Educational Technology course at a Malaysian public university.

A case study design was selected to enable in-depth exploration of Design Thinking as it was enacted within an authentic instructional setting. The case was bounded to a single semester course in which student teachers engaged experientially with the five phases of Design Thinking, namely Empathise, Define, Ideate, Prototype, and Test through the creation of educational tabletop games. Rather than analysing Design Thinking at a purely theoretical level, the study focused on its situated application within a sustained, real-world design task.

Researcher Positionality

The researcher served as the facilitator of the game design project and concurrently acted as a non-participant observer. This dual role provided sustained access to participants' interactions, artefact development, and iterative decision-making processes. To mitigate potential bias, reflexive field notes were maintained throughout the study, and multiple data sources were triangulated. Member checking and peer debriefing further supported the credibility and transparency of interpretations.

Educational Tabletop Game Design Task

Tabletop games were selected as the design medium due to their practical advantages for classroom use. Tabletop games were selected because they do not require technical infrastructure or programming skills, which makes them accessible in a wide range of educational settings (Engelstein and Shalev, 2022). Their clear goals, structured rules, and active player interaction support the integration of learning objectives, while their tangible format encourages collaboration among learners (Boller and Kapp, 2017; Martin et al., 2021). The physical and low-cost nature of tabletop games also makes them suitable for classrooms that have limited resources (Hsieh et al., 2023). These characteristics make tabletop games an appropriate medium for student teachers to practise designing instructional materials that are both engaging and pedagogically grounded.

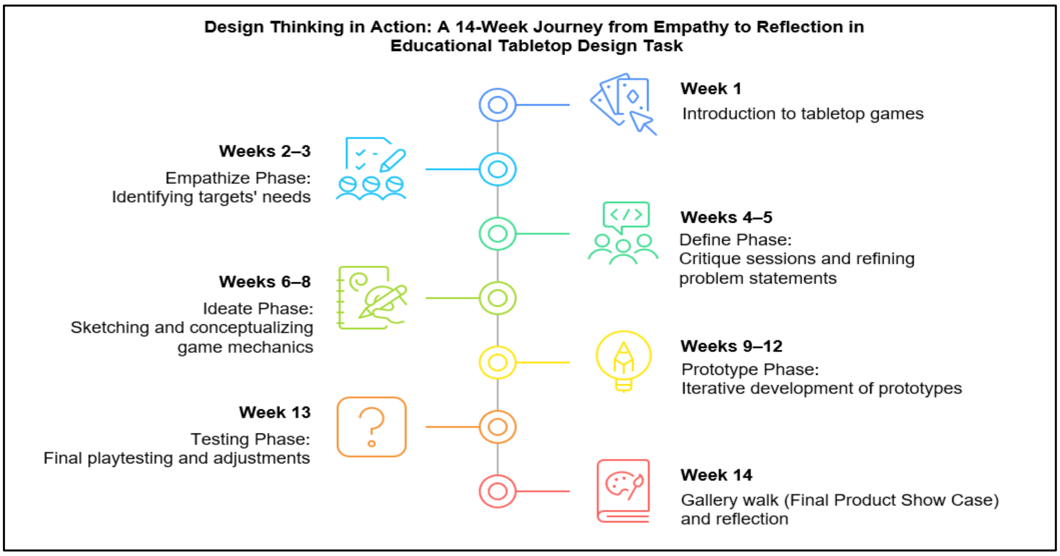

Figure 2: Timeline of the 14-week educational tabletop game design task, structured around the five phases of Design Thinking

The design task required participants to apply the five phases of Design Thinking across a structured fourteen week timeline. Throughout this process, participants analysed existing educational and commercial games, conducted informal consultations with potential users, generated design concepts through brainstorming and sketching, constructed low- and mid-fidelity prototypes using accessible materials, and engaged in iterative playtesting to refine mechanics, rules, and instructional alignment. The timeline of the 14-week educational tabletop game design task is shown in Figure 2.

To ensure the task's clarity, appropriateness, and alignment with course learning outcomes, the project brief, instructions, and assessment rubric were reviewed by three experts in instructional design and Design Thinking. Their feedback focused on the feasibility of the Design Thinking workflow for student teachers, the suitability of tabletop game creation as a learning activity, and the alignment between the design task and broader curriculum standards. Minor refinements were made to the instructions based on their recommendations to improve task clarity and ensure that all phases of the Design Thinking process were meaningfully operationalised.

Participants and Setting

Participants were student teachers enrolled in a compulsory Educational Technology course at a Malaysian public university. A total of 12 groups across three classes completed the tabletop game project as part of the course activities. Using a purposive, criterion homogeneous sampling strategy, the researcher worked with the course instructors to identify groups that met the inclusion criteria: (a) enrolment in the Educational Technology course during the study semester, (b) status as second year students or above to ensure basic curriculum knowledge, (c) full attendance throughout the fourteen week Design Thinking project to ensure exposure to all phases of the process, and (d) willingness to participate in follow up focus group discussions and document sharing. Two groups from each of the three classes were selected through this consultative process, resulting in six groups and a final sample of 22 student teachers.

This purposeful selection balanced the need for information rich cases with feasibility for in depth analysis and allowed for cross cohort comparison while controlling for key background characteristics. Throughout the study the researcher sought to build and maintain rapport with participants to support open reflection and rich data collection All participants provided written informed consent, and pseudonyms were used to protect confidentiality. Ethical procedures followed institutional guidelines and the principles of the Declaration of Helsinki.

Data Collection and Data Analysis

Data collection was conducted throughout the 14-week Design Thinking project and closely followed the sequence of activities undertaken by the participants. The researcher attended 10 three hour sessions for each class, observing how student teachers engaged with the five phases of the Design Thinking framework. These observations captured natural interactions, collaborative decision making, and the evolution of ideas and prototypes over time. Detailed field notes were recorded during each session, supported by still photographs and video clips documenting key stages of the design process, including brainstorming activities, sketch development, prototype construction, and informal testing moments

A distinctive feature of the data collection was the implementation of cultural probes (Gaver et al., 2004) through weekly e-portfolios on the Padlet online platform. This innovative documentation approach captured the design process through multiple modalities: written reflections, visual documentation including sketches and mind maps, photographic evidence of prototypes, and video recordings of testing sessions. In addition to observations and e portfolios, the researcher conducted 24 focus group discussions, with each group participating in three to four sessions across the project timeline. These discussions invited participants to reflect on their planning decisions, challenges encountered, evaluation of game features, and experiences of iterative refinement. Focus groups also offered opportunities for participants to articulate their understanding of each Design Thinking phase in relation to their developing games.

Document analysis was conducted on all design artefacts generated throughout the project. These artefacts included early sketches, rule drafts, mind maps, prototype components, final board layouts, and completed game products. Photographs of these materials were systematically captured during observations to capture the development of ideas and the evolution of game structures. When aspects of the artefacts were unclear, the researcher requested clarification from participants during observations or focus group discussions to ensure accurate interpretation of their design intentions and reasoning. This process allowed for a comprehensive reconstruction of group design journeys and supported the triangulation of findings across data sources.

Data were analysed using reflexive thematic analysis following Braun and Clarke’s (2021) procedures. The researcher first reviewed all observational notes, e portfolio entries, focus group transcripts, and design artefacts to develop familiarity with the data. Initial codes were generated inductively to capture actions, reflections, and recurring patterns related to participants’ engagement with each Design Thinking phase. A preliminary code structure was developed and reviewed with a second qualitative researcher, with differences in interpretation resolved through discussion. Themes were then organised by comparing coded data across the six groups and verifying consistency across multiple data sources.

Data sufficiency was indicated when no new codes emerged during later stages of analysis and similar patterns appeared across groups. Member checking sessions allowed participants to confirm the accuracy of theme interpretations, while peer debriefing with external qualitative researchers strengthened the credibility of analytic decisions. An audit trail documenting coding steps and analytic reflections was maintained throughout the study

FINDINGS

To systematically discover how student teachers applied Design Thinking in educational tabletop game creation, the findings are organized according to the five-phase Design Thinking framework (Stanford d. School, 2018) and its iterative nature. This structure reveals how participants experienced each stage of the design process while developing the tabletop games, providing valuable insights into both the practical application of Design Thinking.

Participants Profile

The study participants were selected from three distinct classes within the Faculty of Education: two Physical Education classes (Class A and Class B) and one Malay Language Education class (Class C). Classes A and B each comprised 28 students, organized into 7 groups of 3 students per group, contributing a total of 56 students and 14 groups. Class C consisted of 41 student teachers divided into 13 groups, with each group containing 3 to 4 members. All participants were fifth-semester students enrolled in an Educational Technology course. For anonymity, pseudonyms were assigned to each group and participant, with representative groups labelled as Group 1 and Group 2 (Class A), Group 3 and Group 4 (Class B), and Group 5 and Group 6 (Class C). The final sample included 22 students (16 from Physical Education and 6 from Malay Language Education) reflecting the programmatic diversity of the cohort. The gender distribution was balanced, with 12 males (54.54%) and 10 females (45.45%), and all participants were aged either 22 or 23 years.

Empathize: Understanding Learner Needs

Student teachers employed a multi-method approach to investigate authentic classroom needs during the Empathize phase, combining direct research with reflective practices. All six groups conducted interviews with in-service teachers, with five groups utilizing digital platforms, namely WhatsApp and Google Meet (as shown in Figure 3 and 4), while one group conducting in-person interviews at a local secondary school. These interviews yielded critical insights into instructional challenges, as evidenced by participant reflections:

"Through interviewing Physical Education teachers, we discovered cricket instruction suffers from equipment shortages and the lack of a cricket field…" (Student Teacher E, FGD1/S3/18-23)

"We interviewed the Head of the Malay Language Panel and two Malay language teachers from my old school via WhatsApp. The teachers confirmed that students struggle most with grammar concepts, which are taught through rote memorization." (Student Teacher X, FGD6/S3/34-38)

Figure 3: Screenshot of WhatsApp interview dialogue showing student teachers consulting with two experienced Malay Language teachers. The discussion identifies key challenges in teaching Malay grammar that informed the game's design objectives (e-portfolio Student X: Group 6)

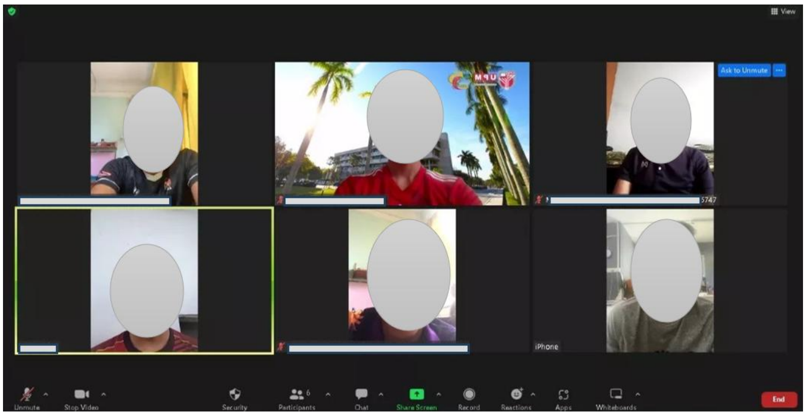

Figure 4. Google Meet interview session with Physical Education teachers (e-portfolio Student J: Group 3)

To broaden their understanding of students' learning challenges, two participant groups (Group 1 and Group 6) administered online surveys using Google Forms (as shown in Figure 5). These surveys were designed to gather data on students' difficulties and preferences in their respective subjects. The groups used online surveys due to their efficiency in reaching a large number of respondents quickly. By distributing the survey links through selected teachers, they ensured widespread participation while minimizing logistical challenges. The surveys aimed to identify the most challenging topics within each subject, as well as students' learning preferences. This approach allowed the groups to collect quantifiable data, complementing the qualitative insights obtained from teacher interviews.

"Actually, we have been facing difficulties in contacting students. That is why we distributed online survey forms through teachers to students so that it would be faster and could get a lot of data." (Student Teacher B, FGD1/S3/43-45)

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"After the interview, we distributed the questionnaire via Google Form to 10 teacher respondents. The 10 teachers were from 3 schools." (Student Teacher X, FGD6/S3/20-21)

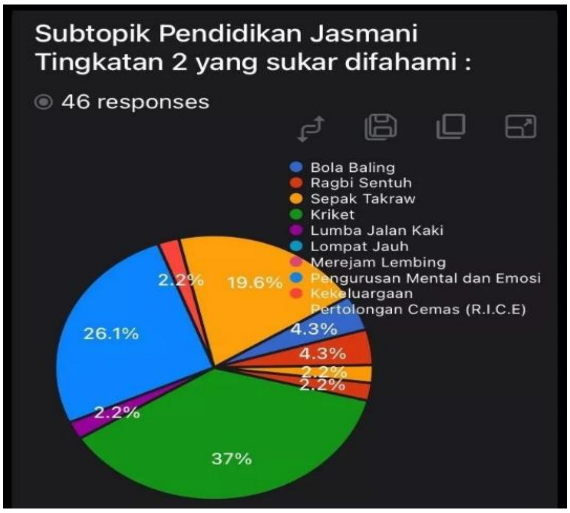

Figure 5: A screenshot of the survey results extracted from the e-portfolio of Student B Group 1, showing 46 Form 2 students' perceived difficulties in Physical Education topics. Cricket emerged as the most challenging topic (37% of respondents), with students citing lack of prior exposure, inadequate facilities, and unfamiliarity with the sport as primary barriers.

Surprisingly, all groups enriched these findings through deliberate reflection on their own educational experiences. During the observations in the classroom, the researcher noted that the student teachers engaged in lively discussions as they recalled their past learning experiences. They shared stories about how their teachers delivered certain topics, what worked well, and what could have been improved. For instance, participants of Group 5 discussed how their Malay Language teacher used memorizing method to teach grammar, which made the subject difficult to understand. Participants of Group 3 reflected on how their Physical Education teacher focused heavily on theory without providing practical demonstrations on the first aid unit, which left them unprepared for real-life situations. During focus group discussions, participants drew parallels between their past struggles as students and the current challenges identified in their research.

"Our own secondary school experience mirrored these challenges - first aid was taught theoretically without practical application." (Student Teacher J, FGD3/S2/18-20)

"We struggled with Malay adverb just as current students do, due to overly abstract teaching methods." (Student Teacher I, FGD5/S3/30-32)

Define: Identifying the Main Instructional Problem

Building upon insights from the Empathize phase, student teachers systematically analyzed their findings to develop focused problem statements. The Define phase involved two key processes: categorizing issues into thematic clusters and developing comprehensive overviews of core challenges. This structured approach transformed raw empathy data into focused design challenges.

Four groups (Groups 2, 3, 5, and 6) employed structured categorization techniques using sticky notes and comparison charts (as shown in Figure 6). This visual approach helped identify recurring themes from interview data:

"We grouped problems and needs using sticky notes during discussions, focusing on solvable issues like teaching methods rather than systemic constraints." (Student Teacher R, FGD5/S2/33-35)

"By comparing teacher responses, we identified pronouns as the most challenging grammar concept." (Student Teacher V, FGD6/S2/53-54)

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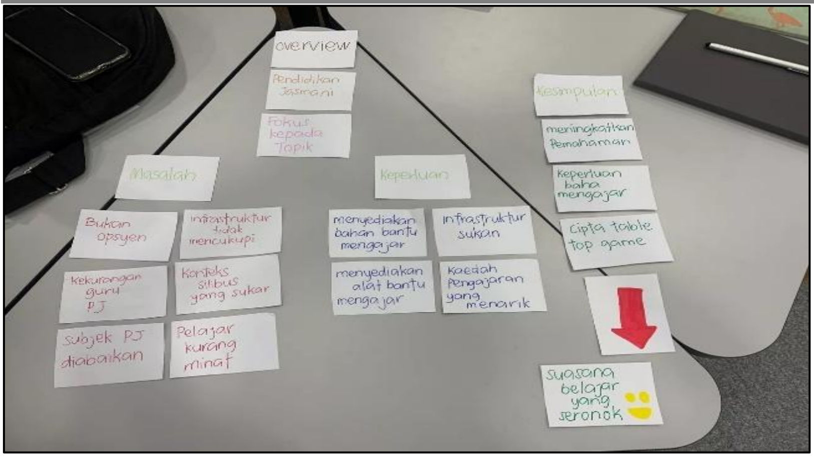

Figure 6: The categorization of data into problems and needs of the target group of Group 3. The image displays sticky notes with keywords and themes organized on a table, illustrating the group's process of identifying common issues. (e-portfolio Student I: Group 3)

Groups 2 and 4 took a holistic approach, synthesizing data into comprehensive problem statements. This comprehensive summary provided a clear picture of the specific challenges faced by educators in teaching the subject matter. They summarized and viewed the data and issues as a whole. This step helped the participants understand the broader context and the systemic issues that needed to be addressed for the ideation phase.

"After the interview, we can conclude comprehensively and make an overview that the main problem in learning dodge ball is the problem of facilities and dodge ball equipment. The main issue was clearly discussed during the interview with the teacher." (Student Teacher O, FGD4/S2/53-55)

Analysis of e-portfolio photos and researcher observations revealed three key strategies student teachers employed to refine their problem definitions. First, they systematically distinguished between solvable instructional challenges (such as abstract teaching methods) and systemic constraints beyond their project scope (like resource allocation). Second, they identified high-frequency issues through comparative analysis of interview responses, noting which challenges were mentioned most consistently across different teachers. Third, they prioritized problems particularly suited to game-based solutions, focusing on areas were interactive, experiential learning could make the greatest impact. This strategic filtering process was documented visually in their e-portfolios through annotated sticky note walls and comparison charts showing their progressive refinement of focus areas.

Ideate: Generating Game Concepts

Building upon the defined challenges, student teachers engaged in creative exploration to generate innovative game solutions. The Ideate phase involved four complementary approaches: collaborative brainstorming, digital research, experiential adaptation, and visual conceptualization.

All groups employed structured and collaborative brainstorming techniques using mind maps and idea journals (as shown in Figure 7). During these collaborative sessions, groups systematically generated and evaluated multiple ideas while considering critical design factors. As reflected in focus group discussions, teams carefully assessed each concept's feasibility based on key parameters including: cost efficiency, design complexity, material requirements, educational content alignment, and game rule structure.

"We generated ideas freely during brainstorming sessions, considering materials, rules, and content integration simultaneously." (Student Teacher F, FGD2/S2/74-77)

"We brainstorming to get ideas. Each group member is free to express their own opinions, there is no right or wrong. During brainstorming, we noted down each other's opinions. From the ideas collected, we find and choose which ones are the best and most suitable according to the objectives." (Student Teacher U, FGD5/S3/90-93)

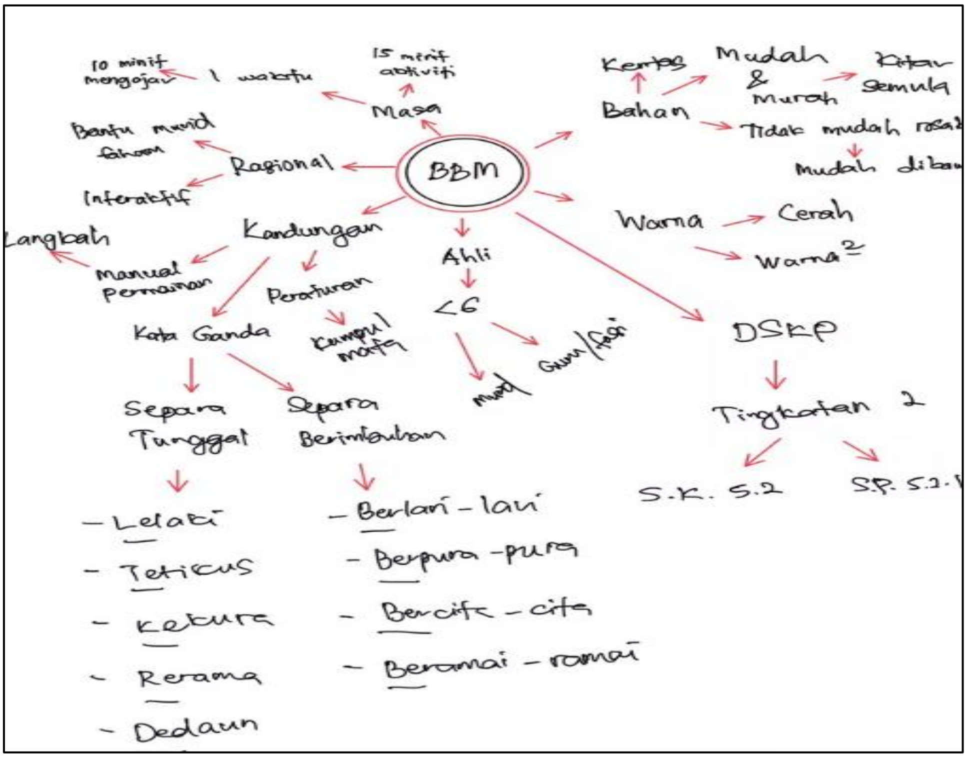

Figure 7: A mind map created by Group 5 demonstrating systematic brainstorming for their "Kata Ganda" (Double Words) Malay Language game. The visualization organizes key design considerations including game mechanics, material requirements, and curriculum alignment strategies (e-portfolio Student R: Group 5).

Three groups (Groups 1, 4, and 6) supplemented their ideation with digital inspiration from online platforms:

"YouTube tutorials helped us adapt digital cricket simulations into physical game components" (Student Teacher D, FGD1/S3/81-84)

"TikTok's video demonstrations inspired our approach to teaching dodgeball strategies" (Student Teacher N, FGD4/S2/69-70)

For experiential adaptation, participants drew extensively on their personal gaming histories, modifying familiar tabletop and childhood games to meet educational objectives:

"Our puzzle-based game emerged from recalling commercial puzzle mechanics and adapting them to teach muscle anatomy." (Student Teacher E, FGD2/S2/65-69)

"We transformed childhood medical play-sets into a first aid training game by adding authentic treatment scenarios." (Student Teacher I, FGD3/S3/104-109)

Analysis of e-portfolio and observations revealed three key ideation strategies. First, participants employed divergent-convergent thinking, initially encouraging wild ideas before systematically evaluating feasibility. Second, they blended multiple inspiration sources, combining digital research with personal gaming experiences and pedagogical requirements. The researcher observed that participants frequently referenced and analysed their prior gaming experiences during discussions, using these familiar games as inspiration for their designs. They actively identified enjoyable game mechanics from their personal play history and adapted them for educational purposes. Third, they rapidly visualized concepts through sketches, enabling quick iteration and refinement before prototyping (as shown in Figure 8 to 12). This creative synthesis process was documented through progressive sketch iterations and annotated mind maps in their e-portfolios.

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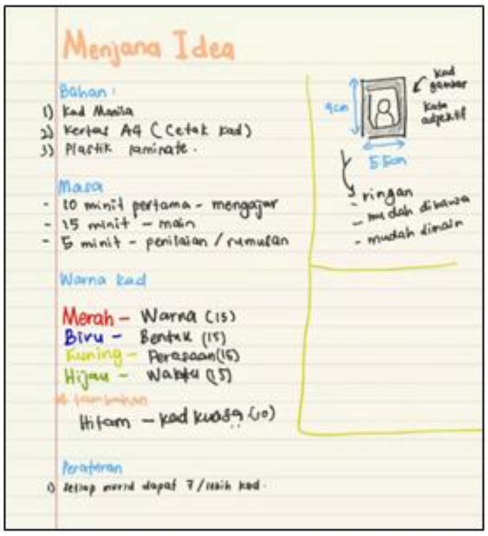

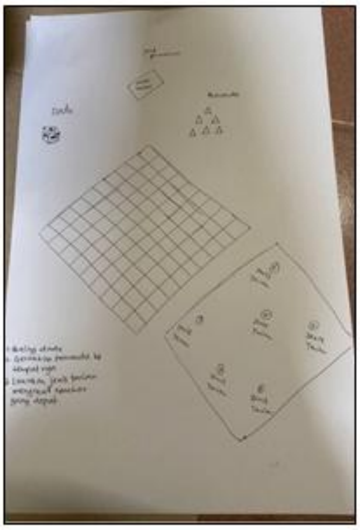

Figure 8,9,10: Samples of simple hand-drawn sketches to draft their initial ideas of Group 1, Group 2, and Group 6

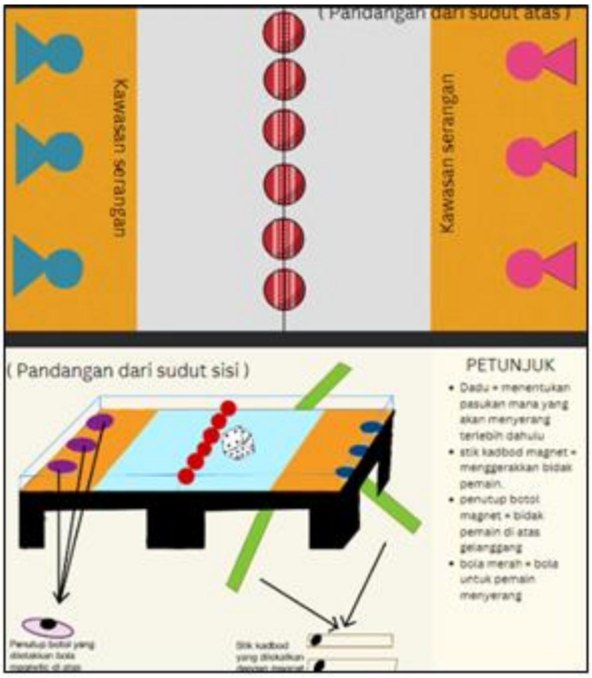

Figure 11, 12: Samples of final sketches to visualize the game ideas Group 3 (RICE Method in First Aid) and Group 4 (Dodgeball). The sketches illustrating complete game concepts with detailed annotations. The drawings visually present gameplay mechanics, instructional components, and color-coded design elements alongside explanatory notes about their pedagogical functions.

All groups developed game concepts that balanced three key elements: (a) direct alignment with identified learning challenges, (b) practical classroom implementation considerations, and (c) engaging mechanics adapted from familiar game formats.

Prototype: Bringing Ideas to Tangible Form

Building upon the conceptualized game ideas, student teachers transitioned into physical experimentation by developing low-fidelity tabletop prototypes. The Prototype phase involved three processes: material construction, internal playtesting, and collaborative refinement. This phase allowed participants to test the usability of their game ideas by examining the overall gameplay experience, design, mechanics, rules, content, and integration methods. Through this process, they evaluated the accessibility of their games and

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refined the placement of interactive elements, using prototype data to make rapid improvements that enhanced the user experience.

All participant groups constructed initial tabletop game prototypes using readily available, low-cost materials to physically realize their conceptual designs. These preliminary versions, created from recycled materials (as shown in Figure 13 and 14) such as cardboard, paper, and wooden blocks, served multiple purposes: enabling rapid iteration, testing game mechanics, and identifying design flaws while adhering to sustainable practices.

“Our initial paper-based court design revealed structural weaknesses, prompting successive improvements from folded A4 paper to cardboard boxes, and finally to durable green cardboard. Without physical prototyping, we wouldn't have identified these critical flaws.” (Student Teacher A, FGD1/S3/108-113)

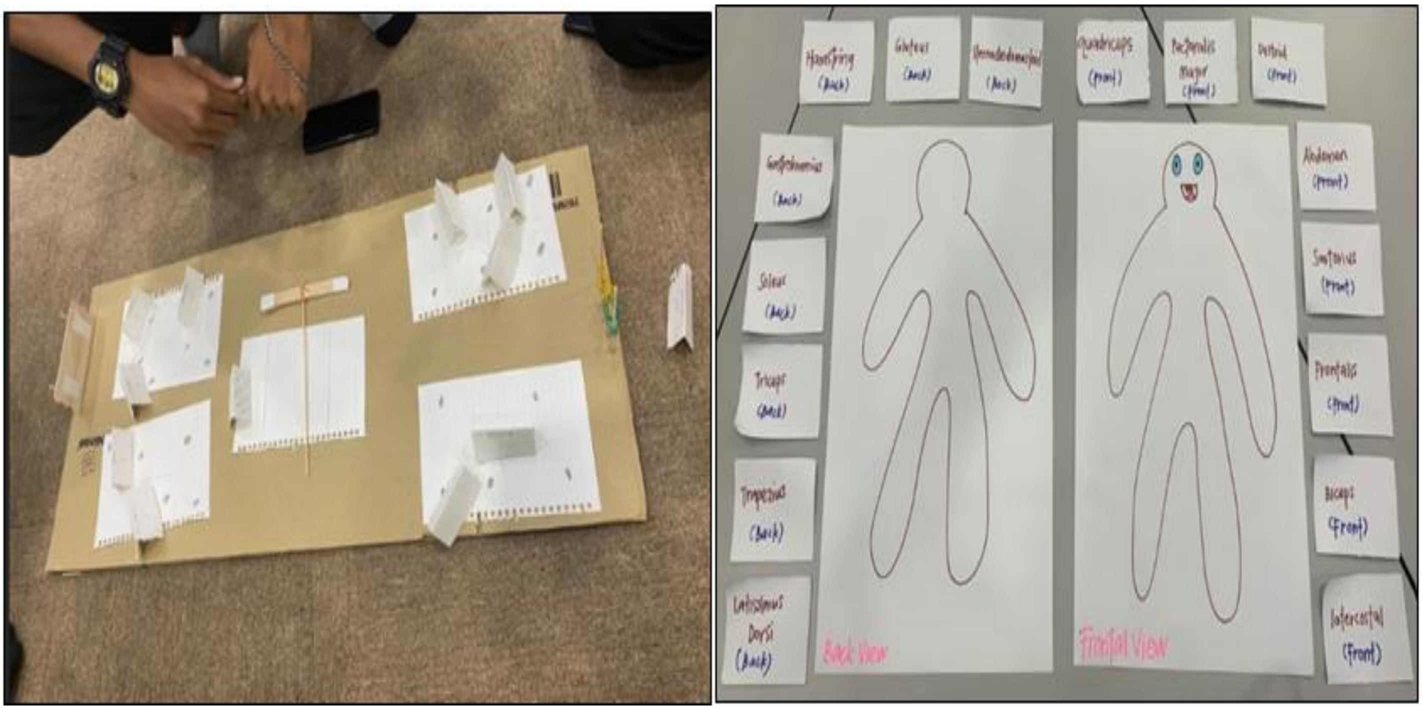

Figure 13, 14: Participants from Group 1 and Group 2 creating their tabletop game prototype using recycled materials, including reused paper, cardboard boxes, and ice cream sticks.

All groups refined their designs through structured internal playtests to evaluate and refine their game prototypes. This iterative process involved comprehensive assessment of game mechanics, rule clarity, material durability, and overall interactivity through repeated gameplay simulations. Participants critically examined each design element while playing, then collaboratively discussed potential improvements within their groups. To ensure well-rounded feedback, groups supplemented their internal evaluations with external perspectives from both the course instructor and peers.

“Based on play test feedback from peers, we upgraded to a thicker game board with reinforced side pillars, creating smoother magnetic piece movement during gameplay.” (Student Teacher M, FGD4/S3/125-127)

“We completely revised our question cards and added thematic elements after testing revealed mismatches with curriculum standards and engagement goals.” (Student Teacher T, FGD5/S3/140-142)

Analysis of field notes and e-portfolios identified three prototyping patterns. First, participants prioritized functionality over aesthetics, using handwritten components for rapid iteration. Second, they adopted modular designs, allowing easy replacement of flawed elements (e.g., swapping a4 paper for sturdier cardboard) (as shown in Figure 15 and 16). Third, they iterated based on feedback, combining peer observations, instructor input, and self-reflection.

Figure 15: Participants of Group 1 were modifying their prototype by changing the materials of the game to make it more durable and stable during gameplay sessions

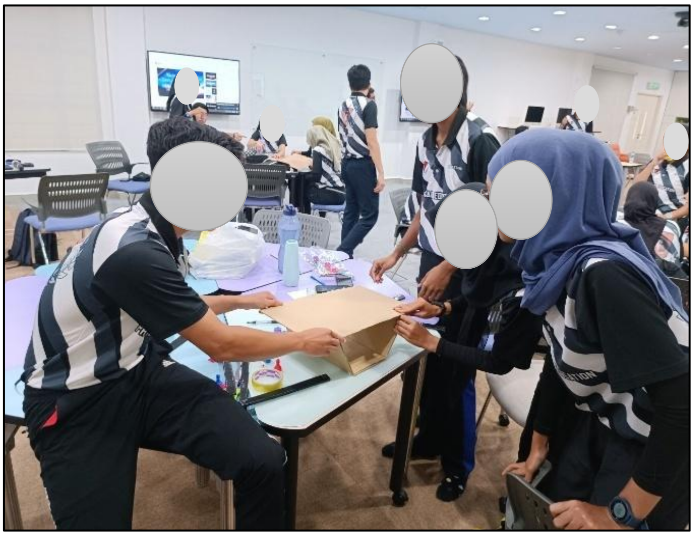

Figure 16: Participants from Group 4 were using a thicker board, smoothing the surface, and adding support pillars to strengthen their board structure and improve gameplay functionality.

All groups achieved prototypes that addressed three criteria: (a) durability for repeated classroom use, (b) alignment with learning objectives through embedded content, and (c) accessible gameplay requiring minimal teacher intervention.

Testing: Evaluating and Refining the Games

Building upon their prototyped designs, student teachers engaged in systematic evaluation to refine their tabletop games' educational effectiveness and playability. The Test phase involved three key processes: structured playtesting, comprehensive feedback collection, and iterative refinement. This phase enabled participants to assess the learning impact of their games by examining player engagement, knowledge retention, rule clarity, and material durability, using test data to make targeted improvements that enhanced both educational value and user experience.

All six groups conducted classroom-simulated playtests with peers, instructors, and target users (as shown in Figure 17 and 18). These sessions revealed crucial insights about game effectiveness:

“We asked testers to evaluate whether the rules were clear, the content was memorable, and most importantly, if they had fun learning.” (Student Teacher A, FGD1/S3/131-133)

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"After testing our game, peers and instructors really gave us a lot of useful feedback based on their game-play experiences. Otherwise, we would still be stuck in the same place, ideas not developing, unable to see the weaknesses of our game." (Student Teacher J, FGD3/S3/237-240)

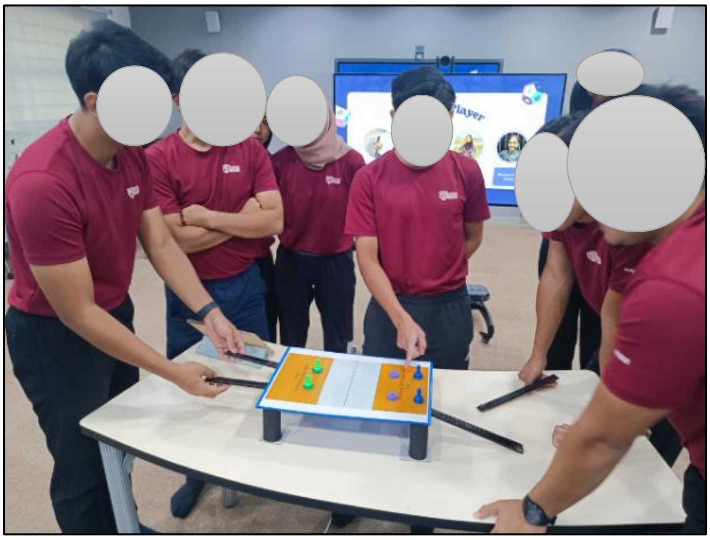

Figure 17, 18: Participants from Group 4 and Group 6 conducting playtest with peer evaluation

All groups also implemented significant refinements based on testing feedback. After collecting the feedback during testing, participants analysed it to understand their games' strengths and weaknesses. Using this insight, they made necessary changes, namely modifying game rules, adjusting gameplay mechanics, changing materials, refining the design, and ensuring the content was suitable for the target audience—to enhance both the user experience and educational value.

"Peer testing revealed our cricket rules were too complex for beginners. We simplified the scoring system and replaced fragile components with classroom durable materials, making the game more accessible for first-time players." (Student Teacher C, FGD1/S3/159-162).

"Feedback transformed multiple design elements of our game from color choices to rule explanations. We incorporated all feedbacks, resulting in a more visually coherent and intuitively playable final version." (Student Teacher T, FGD5/S3/162-164).

Analysis of observation notes and e-portfolios revealed three key testing outcomes. First, groups successfully balanced educational objectives with entertainment value, ensuring knowledge retention without sacrificing engagement. Second, they demonstrated adaptive design thinking by rapidly incorporating feedback from multiple stakeholders (peers, instructors, and target users).

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Figure 19, 20: Final products from Group 2 and Group 6. The games were modified in terms of materials, game mechanisms, and rules based on feedback from peers during the testing phase.

Iterative Process: Bridging Design Phases through Continuous Refinement

Building upon their design experiences across all phases, student teachers engaged in continuous cyclical refinement to optimize their tabletop games. This process involved returning to earlier ideas, revising game mechanics, adjusting design features, and modifying rules based on feedback from peers, instructors, and self-assessment. Although iteration is not a distinct phase, it is embedded throughout the Design Thinking process, enabling continuous improvement and innovation. This approach enabled participants to systematically improve their designs while maintaining alignment with learning objectives and user needs.

All six groups demonstrated iterative practices through multiple design cycles. Their process consistently followed a pattern of prototyping, testing, then returning to ideation for refinement:

“Our design process became a continuous loop - we would develop an initial concept, build a prototype, test it with peers, then use that feedback to revisit and improve our ideas before creating the next version.” (Student Teacher A, FGD1/S3/103-106)

“After testing our second prototype, we realized we needed to rethink some of the core mechanics. Instead of just making minor adjustments, we went back to the drawing board to come up with better solutions.” Student Teacher L, FGD3/S2/101-104)

“Our design process began with empathy, problem definition, and brainstorming before prototyping. After peer feedback, we cycled back through ideation, created improved prototypes, and conducted further testing. This iterative refinement significantly enhanced our final game quality.” (Student X, FGD6/S3/152-156)

Analysis of design artifacts and field notes revealed three key characteristics of the iteration process. First, groups maintained progressive refinement of core mechanics while preserving educational objectives. Second, they systematically incorporated feedback from peers, instructors and target users at each cycle. Third, participants demonstrated selective regression by strategically revisiting only necessary phases rather than restarting the entire process.

DISCUSSION AND CONCLUSION

The findings of this study demonstrate that the five phases of Design Thinking provided a coherent structure for guiding student teachers through the development of educational tabletop games. Across all groups, participants engaged with the process in ways that both confirm and extend existing research on Design Thinking in education, while offering distinctive insights into how novice educators apply design principles within non-digital instructional contexts.

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In the empathise phase, participants gathered information through interviews, surveys, and reflective discussions, supporting prior emphasis on understanding user needs in early design stages (Gwangwava, 2021; Matsui, 2023). This study extends existing literature by showing how student teachers combined multiple empathy strategies to construct layered interpretations of instructional challenges, drawing on teacher perspectives, student feedback, and personal learning experiences.

The define phase revealed participants' ability to synthesise data into targeted and manageable instructional problems. While consistent with foundational descriptions of Design Thinking as a problem-framing process (Stanford d.school, 2018; Brown, 2019), the findings highlight how novice designers distinguished between issues addressable through game mechanics and broader structural constraints beyond their control. This selective framing complements discussions by Durga (2022) and Matsui (2023) on contextualising design thinking within educational realities.

During ideation, participants relied on brainstorming, sketching, and collaborative reasoning. Their adaptation of familiar game structures echoes Zhang and Chen (2021), while their deliberate alignment of mechanics with learning objectives illustrates a pedagogically grounded interpretation of design strategies. Sketches functioned not merely as visual representations but as tools for collective pedagogical negotiation, extending observations by Moffett and Cassidy (2023).

The prototyping phase reaffirmed the value of low-fidelity experimentation (Kijima et al., 2021), yet the present findings add an important educational dimension: prototypes were evaluated simultaneously for playability and instructional accuracy. This dual evaluative lens distinguishes educational game design from general product design and reflects the integrated judgement required of future teachers. Iterative peer feedback further supported the collaborative design outcomes noted by Bressler and Annetta (2021).

Testing practices aligned with literature emphasising multi-modal evaluation (Luthfi and Wardani, 2019; Kijima et al., 2021), but the findings suggest that testing also functioned as a mechanism for refining pedagogical clarity and instructional coherence. Improvements in rule articulation and outcome alignment reinforce the argument by Kim et al. (2022) that evaluative design activities can deepen professional reasoning.

A key contribution of this study lies in illustrating how iterative cycles between ideation, prototyping, and testing were enacted within the practical constraints of a fixed curriculum. Rather than complete phase repetition, participants engaged in focused, context-sensitive refinements. This extends the systems perspective described by Rösch et al. (2023) by demonstrating how student teachers balanced learner needs, curricular goals, and classroom feasibility through pedagogical design thinking.

The application of Design Thinking in developing educational tabletop games underscores the methodology's flexibility and effectiveness across media formats. While traditionally associated with digital products, this study demonstrates that Design Thinking's human-centred principles translate effectively to non-digital contexts. The methodology's strength lies not in the medium employed, but in its structured, iterative approach to solving educational challenges. Participants' success in creating meaningful, learner-centric games highlights how empathy and continuous feedback integration can guide development even within fixed curricular constraints.

Limitations and Recommendations for Future Study

Several limitations should be considered when interpreting the findings. The study was conducted within a single Malaysian public university and involved a relatively small, purposively selected sample of student teachers, which may limit transferability to other institutional or cultural contexts. The focus on non-digital tabletop game development further bounds the findings, as Design Thinking processes may manifest differently in digital or technology-intensive environments. In addition, the study examined the design process rather than the classroom implementation of the completed games, leaving the impact on learner outcomes unexplored.

Future research could extend this work by examining how the developed tabletop games perform in real classroom environments, particularly by evaluating their impact on student engagement and learning outcomes. Implementing and testing these games with school students would provide valuable insight into how design decisions made by preservice teachers translate into real instructional effectiveness. Longitudinal research may further investigate whether Design Thinking practices cultivated during teacher education are sustained and applied when these individuals enter professional teaching contexts. In addition, expanding the study across multiple institutions or cultural settings would strengthen the transferability of findings and offer broader perspectives on how Design Thinking can support teacher development in diverse educational environments.

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