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Development of a Design-Based STEM Learning Guides for Remote Teaching and Learning Home Economics to Enhance Pre-service Teachers' Creativity

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Abstract. In response to the demand for innovative educational approaches in remote learning environments (RTL), this study explores the potential of design-based STEM (Science, Technology, Engineering, and Mathematics) learning guides in fostering creativity among pre-service teachers (PSTs). Specifically, it aims to develop and evaluate the effectiveness of a design-based STEM instructional guide for RTL in Home Economics education. The study involved six university instructors in Home Economics and 140 PSTs from the Philippines. Data were collected through focus group interviews with university instructors and PSTs, as well as a 5-point scale creativity self-assessment for PSTs. Findings indicate that the design-based STEM learning guides incorporate hands-on activities, increased discussion opportunities, and video materials to enhance engagement and learning outcomes. The guides offer flexible activity options, allowing PSTs to adapt tasks according to their needs, while embedded strategies emphasize skill development and effective time management. A paired t-test indicated a significant increase in creativity levels following the design-based STEM learning guide implementation, with mean scores rising from 2.79 (SD = 1.27) to 3.84 (SD =0.58), $t(30) = 4.21$, $p < .001$, highlighting the guide's significant impact on PST creativity. These results underscore the value of integrating design-based STEM strategies into Home Economics education in

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remote settings, providing valuable insights into fostering creativity and promoting innovative teaching practices. This approach establishes a new benchmark for remote teaching innovation and serves as a valuable blueprint for future research and practice in modernizing teacher education.

Keywords: design thinking; home economics; design–based STEM education; learning guides

1. Introduction

The COVID-19 pandemic in 2020 caused significant disruptions in university education. It not only impacted academic institutions but also reshaped the way individuals interact, communicate, and function in their daily lives. It changed how we socialize, work, and learn (Lemay et al., 2021), forcing students and teachers to transition to remote learning from home. Educational institutions had shut down to reduce and control the spread of the disease (Lemay et al., 2021; Pokhrel & Chhetri, 2021), and this has disrupted the traditional ways and strategies of teaching and learning process (Lemay et al., 2021). This results in institutions evaluating the availability of facilities and the readiness of faculty members, students, staff, and administrators to reconsider other learning modalities. This situation led to the shift from face-to-face to a remote teaching and learning modality (RTL). While this sudden shift spurred new ideas, it also introduced numerous challenges, as higher education institutions had to implement emergency online teaching with minimal preparation (Oliveira et al., 2021). Similarly, students faced various problems and challenges in adapting to the abrupt and unplanned shift to online learning (Baticulon et al., 2021; Lemay et al., 2021). As universities transitioned to remote learning, educators had to adapt both synchronous and asynchronous instructional approaches quickly to ensure educational continuity. This abrupt transition was particularly challenging for courses traditionally reliant on hands-on, laboratory-based learning, creating difficulties in replicating experiential learning activities in remote settings (Albuhairy, 2021). To address these challenges, educators needed to rethink curriculum design, instructional materials, and learning support systems to engage PSTs effectively in remote learning environments (Almahasees et al., 2021; Aristovnik et al., 2020). Structured learning guides, which break down complex tasks into manageable, sequenced steps, played a crucial role in helping PSTs work independently and maintain engagement even without direct instructor supervision.

The transition to remote learning also revealed significant challenges in designing activities that foster creativity among PSTs within the constraints of online education. In-home economics education—where the goal is to equip PSTs with practical skills, technological proficiency, and critical thinking—fostering creativity is essential yet particularly challenging in a remote learning environment (Mamun, 2024). As a performance-based discipline within the K–12 curriculum, Home Economics relies on hands-on, experiential learning to develop competencies in cooking, family finance, nutrition, and other essential life skills (Talosig & Guillena, 2023). However, remote learning environments often lack this experiential component (Eze, 2023; Reponte & Gallardo, 2024). Additionally, isolation, boredom, and technical limitations in online learning can negatively impact PSTs' creativity, motivation, and engagement (Aristovnik et al., 2020; Kapasia et al., 2020). Creative thinking—a core competency in PSTs' professional development—requires the ability to analyze problems, adapt to challenges, and develop solution-oriented approaches, all of which are fundamental to effective teaching practices (Csikszentmihalyi, 2014; Savage & Healy, 2019).

Design-based STEM education offers a promising framework for addressing these challenges by integrating open-ended, product-focused learning that fosters creativity and practical skill development in Home Economics education. This approach promotes experiential learning through real-world problem-solving, enabling PSTs to cultivate critical skills and adaptability (Panergayo & Prudente, 2024). By engaging in hands-on design processes, design-based STEM education equips PSTs with innovative teaching strategies that enhance student engagement and learning outcomes. Furthermore, fostering creativity through design-based STEM activities enables PSTs to develop problem-solving skills that are essential for addressing contemporary educational challenges (Sonthong et al., 2023). While design-based STEM aligns well with Home Economics owing to its emphasis on hands-on, life-skill-oriented projects, research on its effectiveness in remote learning contexts remains limited. The shift to digital learning platforms has underscored the need for adaptive teaching strategies that maintain engagement and hands-on learning opportunities, despite the physical limitations of remote settings (Koh & Daniel, 2022). This gap is particularly evident in studies examining the impact of design-based STEM on enhancing creativity and adaptability in PSTs within remote learning environments, especially considering the unique challenges brought about by the pandemic-induced shift to online education (Delen & Yuksel, 2023). Understanding how PSTs perceive and navigate these challenges can provide valuable insights for improving instructional strategies and fostering more effective remote learning experiences.

Hence, this study aims to bridge this gap by evaluating the impact of design-based STEM instructional guides on fostering creativity among PSTs in remote learning environments. It explores the integration of design-based STEM education, creativity, and remote learning, providing novel insights into how innovative instructional approaches can enhance teacher preparation. Moreover, the study incorporates the design thinking process into Home Economics education, highlighting its potential to enrich pedagogical strategies. The findings contribute to a deeper understanding of the role that innovative, design-based pedagogies play in enhancing creativity and adaptability in teacher education, particularly in remote settings.

1.1 Design-Based STEM Education

Design-based STEM education integrates design thinking into STEM disciplines, emphasizing real-world problem-solving, innovation, and the practical application of knowledge (Barlex & Trebell, 2008). Unlike traditional structured learning, design-based challenges are intentionally open-ended, encouraging PSTs to navigate uncertainty and develop creative solutions (Hang, 2024). Through this open-ended learning process, PSTs are encouraged to engage in deeper inquiry, enhancing their ability to pose meaningful questions and critically analyze information (Panergayo & Prudente, 2024). This approach requires PSTs to produce tangible outcomes, fostering intrinsic motivation, a sense of ownership, and deeper engagement with their learning (Reiser et al., 2024). Furthermore, hands-on engagement in design-based STEM has been shown to enhance cognitive flexibility and metacognitive awareness, which are essential for developing adaptable teaching strategies in dynamic classroom environments (Kanapathy & Azhari, 2024). The design process emphasizes key elements of creativity, including flexibility, divergent thinking, and adaptability, which are crucial for developing solutions in dynamic and unpredictable contexts (Henriksen, 2014).

Additionally, studies suggest that exposure to design-based learning promotes innovation literacy, enabling PSTs to develop an entrepreneurial mindset that can be applied both within and beyond the classroom (Kayyali, 2024). In Home Economics, design-based STEM projects provide a context-driven approach to bridging practical skills with critical and creative thinking, integrating problem-based tasks that immerse PSTs in real-world challenges (Çeliker, 2020). The hands-on, product-oriented nature of Home Economics aligns well with design-based STEM, encouraging PSTs to explore the broader social and environmental implications of their choices (Saratapan et al., 2019). As sustainability becomes an integral aspect of education, integrating eco-conscious design challenges within STEM-based Home Economics projects can cultivate awareness of environmental responsibility and ethical consumption (Yadav, 2024). Additionally, collaborative learning in design-based STEM encourages peer learning and knowledge sharing, which is crucial for fostering a sense of community in remote teaching settings (Xu et al., 2023). This synergy fosters creative engagement through experiential tasks that promote critical self-reflection and innovative thinking (Nobutoshi, 2023).

1.2 Learning Guide for Remote Teaching and Learning in Home Economics
Home Economics remotely presents unique challenges owing to its inherently practical and experiential nature. The lack of hands-on supervision in remote settings necessitates innovative instructional strategies to ensure effective skill acquisition (Kampschulte et al., 2023). To support remote instruction effectively, learning guides must be structured in a way that facilitates independent learning while maintaining engagement and skill mastery (Al-Hawamleh et al., 2022). To address these challenges, remote learning guides should provide clear, step-by-step instructions, specify required materials, and outline expected outcomes to help students develop essential skills without constant supervision (Choi, 2022). Since vocational education prepares students for specific professions and trades, integrating industry-relevant resources into remote learning is essential for maintaining quality and ensuring real-world applicability (Abbey, 2020). Providing flexible options, such as household substitutes for specialized equipment and locally available materials, can help PSTs complete practical tasks without being limited by resource constraints (Ralejoe, 2024).

This approach aligns with research on contextualized learning experiences, which emphasize applying theoretical knowledge to real-life situations to enhance retention and deepen understanding, making them essential for effective remote Home Economics education (Reddy & Revathy, 2024). To further support equitable participation, structured learning guides can enhance accessibility by suggesting alternative materials and modifying activities to accommodate varying student resources (Tyler-Wood et al., 2023). Personalized learning paths, which adapt content based on students' needs and progress, can further enhance accessibility and inclusivity in remote Home Economics education (Amzil et al., 2023). Additionally, incorporating reflective questions at the end of each module or project fosters critical thinking and self-directed learning by prompting PSTs to evaluate their approaches and identify areas for improvement (Albuhairy, 2021). Bridges (2019) emphasizes that effective scaffolding—breaking complex tasks into manageable steps—is essential for building the practical skills central to Home Economics, making structured learning guides a vital tool for remote instruction.

2. Methodology

This study employed a mixed-method research design to evaluate the enhancement of PSTs' creativity through specially designed learning guides in Home Economics courses. Data were collected through focus group discussions, which informed the development of the learning guides. Since the data were obtained firsthand from participants, they are classified as primary data. The research sample included six purposively selected Home Economics teachers and 140 PSTs. The inclusion criteria required that participating teachers be actively teaching Home Economics courses, while PSTs had to be enrolled in a Home Economics degree program. A researcher-developed, validated interview guide questionnaire was used in the focus group discussions to assess PSTs' creativity levels and learning experiences in remote teaching. Ethical approval was obtained from the College of Education Research and Ethics Committee before commencing data collection. The research process followed a five-phase design thinking cycle (Stanford D. School, 2010).

During the empathy phase, focus group discussions were conducted with six Home Economics teachers specializing in various areas, including baking and cake decorating, art education, food and nutrition, and clothing construction. These discussions were guided by a content-validated, researcher-developed questionnaire to explore teachers' teaching experiences and insights regarding design thinking. The interview guide was developed based on a thorough review of relevant literature, alignment with design thinking principles, and consultations with experts in Home Economics education and qualitative research. The questions were designed to elicit in-depth responses, providing valuable insights into the perspectives of Home Economics teachers and PSTs, ensuring a comprehensive understanding of their needs. Content analysis of the focus group discussions further refined these insights, serving as the foundation for designing the learning guide.

Concurrently, PSTs participated in separate focus group discussions guided by a validated questionnaire assessing their creativity levels, learning experiences in remote teaching, and suggestions for effective instructional strategies in an online environment. These discussions were conducted via Google Meet. Content analysis of the discussions provided valuable insights into the perspectives of both teachers and PSTs, helping to define their specific needs. The analysis revealed that teachers required additional training in applying design thinking principles, which directly informed the development of learning activities for the PSTs' culminating projects.

During the ideation phase, researchers used the findings from the empathy phase to collaborate with Home Economics teachers, brainstorming the design-based STEM learning guides for Home Economics courses.

In the test phase, the developed design-based STEM learning guides for remote Home Economics teaching were implemented by six teachers. These structured guides were designed to support students systematically in developing their required outputs using the design thinking process. Each guide consisted of a series of activities with clearly defined steps, student tasks, required technology and resources, and a scheduled timeline. The activities guided students through key phases, including identifying the problem, understanding end users, empathizing, defining, ideating, prototyping, testing, and reflecting. Each step outlined specific actions for students to take, ensuring a structured, organized, and resource-supported approach to problem-solving and completing performance tasks.

The implementation lasted between two to three months, depending on the nature of the project or performance tasks, as different activities required varying amounts of time to complete each phase of the design thinking process. Throughout this period, a structured assessment approach was employed to evaluate the effectiveness of the learning guides. Before using the guides, the PSTs completed a 5-point scale creativity self-assessment to establish a baseline for their creative thinking skills, which involved four dimensions: fluency, flexibility, novelty, and elaboration (Torrance, 1977). After the implementation, they took the same creativity self-assessment again . A t-test was conducted before and after the intervention to determine whether there was a significant improvement in creativity. Additionally, PSTs participated in follow-up interviews to share their perspectives on the learning guides. Their responses were analyzed using content analysis to identify their experiences with the design-based STEM learning guides.

3. Results

The research findings were structured around two main objectives: developing a design-based learning guide for remote Home Economics teaching, and assessing PSTs’ creativity before and during its implementation.

3.1 Development of the design-based learning guide

Data from focus group discussions with six Home Economics teachers informed the development of the guide. Content analysis identified three primary areas of need (Table 1): More Training ranked highest, followed by Immersion and

Benchmarking. These findings underscored the need for more excellent support in helping Home Economics teachers understand and apply design-based STEM principles in remote learning guides.

Table 1: Home Economics Teachers' Needs for Integrating Design-Based STEM Learning Guide

Categories	Frequency	Example of PSTs' answer
More Training	3	We need more training to use design-based STEM education effectively.
Immersion	1	Hands-on immersion would help us understand practical applications.
Benchmarking	1	Benchmarking with other institutions would be beneficial.

These insights informed the development of the learning guide, emphasizing online training resources and frameworks to enhance Home Economics teachers' confidence and ability to facilitate interactive, design-based STEM learning. Consequently, a four-day hybrid webinar series was designed and implemented. This series, involving six teachers, was facilitated by an expert from an international partner university and focused on the concepts and processes of design-based STEM education. During the seminar, the curriculum was reviewed, and teachers developed tailored learning activities aligned with this pedagogical approach. These activities were designed to foster creativity, engagement, and practical application in PSTs' culminating projects across various Home Economics courses. Although six teachers participated in the training and contributed to the development of the learning guide, only five were available for the empathy map interview due to the unavailability of one teacher. Despite this, the active participation of the five educators provided valuable qualitative insights. Their diverse perspectives, shaped by different teaching experiences and school contexts, contributed to a well-rounded understanding of the challenges and opportunities in integrating design-based STEM education into Home Economics.

To explore the perspectives of PSTs on their experiences with remote teaching, data were gathered through a focus group discussion that analyzed common challenges and emotions encountered during remote learning. A total of 140 students participated in the project-making activity using the learning guide as it was an essential component of their coursework. However, owing to the interactive nature of focus group discussions, it was not feasible to include all 140 students. To ensure diverse perspectives while maintaining a format conducive to in-depth engagement, a subset of participants was selected using a snowball sampling technique. This method facilitated the identification of individuals who were both available and willing to provide meaningful insights. Although some students were unable to participate owing to scheduling conflicts, efforts were made to ensure a representative range of experiences within the discussion.

Given the need for active engagement and in-depth discussion, only a subset of participants was selected to ensure a meaningful and focused exchange of insights. This approach facilitated a rich exploration of perspectives while maintaining a diverse representation of student experiences in remote teaching. These principles guided the analysis presented in Tables 2 to 4, which capture the emotions and experiences associated with remote teaching and the PSTs' suggestions for improving Home Economics instruction.

As shown in Table 2, participants expressed a range of emotions, from feelings of challenge and frustration to more positive sentiments such as gratitude and excitement.

Table 2: PSTs' Perspectives on Experiences in Remote Teaching

Categories	Frequency	Example of PSTs' answer
Challenging	10	Remote learning is challenging. Learning independently is tough; I feel lost without having someone to demonstrate the tasks directly.
Frustrated	8	I often feel frustrated owing to technical issues and limited support.
Anxious	6	I am anxious about managing my tasks without direct supervision.
Happy and thankful	5	I feel thankful for the flexibility remote learning provides.
Excited	3	I am excited to apply what I learn in a different setting.

A subset of 32 participants was randomly selected from the 140 students to ensure diverse perspectives while maintaining a manageable and in-depth discussion. This sample size provided a well-rounded representation of the population and facilitated meaningful engagement. The analysis highlighted the varied impacts of remote learning and underscored the need for instructional guides that enhance communication, increase engagement, and provide emotional support.

Furthermore, data analysis of PSTs' experiences revealed both the advantages and challenges of remote learning (Table 3). The key benefits identified included Knowledge Application and Skill Development, while the most common challenges were Poor Internet Connectivity and Lack of Resources.

Table 3: PSTs' Positive and Negative Experiences in Remote Learning

Experience	Categories	Frequency	Examples of PSTs' answers
Positive	Knowledge Application	5	I could apply what I learned in real-life scenarios, which made the lessons more relevant.
	Skill Development	4	I developed new skills in time management and self-discipline through remote learning.
Negative	Poor Internet Connection	6	Frequent disconnections made it difficult to follow along with lessons.
	Lack of Tools or Resources	5	I could not complete assignments because I did not have the necessary materials at home.

A subset of 20 participants was randomly selected from the 140 students to ensure diverse perspectives while maintaining a manageable and in-depth discussion. This sample size provided a well-rounded representation of the population and facilitated meaningful engagement. Insights from these discussions informed the development of the learning guide, which incorporated solutions to address internet and resource constraints, offered flexible activity options, and integrated strategies to enhance skill development and time management. Moreover, PSTs' suggestions were analyzed to refine teaching methods for remote Home Economics courses. As outlined in Table 4, participants prioritized Actual Activities as their top preference, followed by More Discussions and Video Materials.

Table 4: PSTs' Suggestions to Home Economics Teachers

Categories	Frequency	Examples of PSTs' answers
Practical activities	8	Include more practical, hands-on projects we can try at home.
More discussions	6	Allow more time for interactive discussions to share ideas.
Provide video materials	4	Provide step-by-step video tutorials for complex tasks.

A subset of 18 participants was randomly selected from the 140 students to ensure diverse perspectives while maintaining a manageable and in-depth discussion. This sample size provided a well-rounded representation of the population and facilitated meaningful engagement. Based on the data analysis in Tables 1 to 4, teachers developed a learning guide that integrates practical activities to enhance student engagement and improve learning outcomes. PSTs collaborated in groups to create prototypes, including clothing for breastfeeding mothers, adaptations for individuals with disabilities, and children's wear. In the baking and pastry production segment, PSTs customized recipes to meet client needs, developing options such as low-sugar cakes and fruit-based desserts. Additional activities in family and consumer life skills courses focused on home decluttering, organization, and beautification. These activities were designed to be flexible, allowing PSTs to adapt tasks according to their available resources and individual learning needs. Embedded strategies emphasized skill development and time management, ensuring a structured yet adaptable learning experience.

To ensure a comprehensive learning experience, Home Economics teachers first equip PSTs with essential prior knowledge and skills before prototype development. This preparation involves integrating discussions and lectures, consulting field experts, and incorporating video materials during the ideation phase. Additionally, a structured learning guide with clear and detailed instructions supports PSTs in effectively navigating the learning process.

The integration of hands-on activities directly addresses PSTs' need for engagement, as highlighted in the focus group discussions. PSTs expressed a strong preference for more practical activities and emphasized that collaborative work was essential for enhancing their learning experience. One PST stated, "*Yes, it gives me a detailed idea of what to do. It's the starting point of my actions, helping me understand client needs and identify problems.*" Another student noted, "*This activity guide helped me understand what I should do first and what to do next,*" highlighting the guide's role in providing structure. Additionally, PSTs appreciated the streamlined approach, with one participant stating, "*The activity guide assists us in completing our tasks more quickly and efficiently.*"

3.2. Pre-Service Teachers' Creativity Before and After Implementing the Learning Guide

Creativity was a key component of PSTs' learning and skills they sought to develop further during remote teaching and learning. Table 5 compares the creativity levels of PSTs before and after completing the activities in the learning guide.

Table 5: Paired T-test for the Mean Creativity Level Comparison of the PSTs Before and After Completion of the Activity in the Learning Guide

Level of Creativity	N	Mean	SD	T	P-value
Before	33	2.79	1.27	-4.21	0.0001*
After	31	3.84	0.58		

*Significant at 5% alpha level

Of the 140 students recruited, 33 participants initially took part in the focus group discussions. However, owing to unforeseen circumstances such as scheduling conflicts, the number of active participants had decreased to 31 by the conclusion of the discussions. Despite this adjustment, the final insights were gathered from those who could fully engage in the process, ensuring a diverse representation of perspectives. To assess whether there was a statistically significant difference in PSTs' creativity levels before and after completing the learning guide activity, a paired samples t-test was conducted. The assumptions of the paired t-test were evaluated prior to analysis. Since the data consisted of two related samples (pre- and post-activity creativity scores), the use of a paired t-test was appropriate. The normality assumption was assessed using the Shapiro-Wilk test, which indicated no significant deviations from normality. The results showed that the mean creativity score before the activity was 2.79 (SD = 1.27), whereas after completing the activity, the mean increased to 3.84 (SD = 0.58). A significant mean difference was observed, $t(30)=-4.21$, $p = .0001$. Since the p-value was below the conventional significance level ($\alpha=.05$), the null hypothesis was rejected, indicating a statistically significant increase in creativity levels following the intervention. These findings indicate that engaging with the learning guide had a meaningful, positive impact on PSTs' creativity, and further suggest the effectiveness of the guide in fostering the development of creative skills.

From a statistical perspective, comparing two inhomogeneous datasets requires careful consideration of the assumptions underlying the chosen test. A paired t-test assumes that data are collected from the same participants and that the differences between paired observations are normally distributed. Minor variations in sample size may occur owing to participant dropout or missing data; however, the test remains valid as long as the remaining pairs are intact. Although the standard deviations in the pre-and post-activity conditions differ, the paired t-test remains appropriate because it evaluates the distribution of the difference scores rather than the raw scores in each condition (Park & Hwang, 2022). The critical assumption is that the difference scores (i.e., "after" minus "before") follow a normal distribution. In this case, the reported p-value confirms that the results are statistically significant despite the slight mismatch in sample sizes. This suggests that the observed increase in creativity scores is unlikely due to random chance and instead reflects a genuine effect of the learning guide activity.

4. Discussion

This research aimed to enhance PSTs' creativity through the implementation of design-based STEM education, specifically by integrating the design thinking process into Home Economics courses during remote teaching and learning. The findings revealed a strong need for additional training in design thinking, as well as opportunities for immersion and benchmarking, highlighting the crucial role of teacher preparedness in effectively integrating innovative pedagogical strategies (Kara et al., 2019). In response, a tailored learning guide emphasizing practical activities was developed, fostering greater PST engagement and creativity.

PSTs' experiences during remote learning were characterized by both challenges and positive outcomes. While many expressed frustration and anxiety, they also recognized valuable opportunities for skill enhancement and applying their knowledge. This aligns with existing literature on the unique challenges faced by adult learners in online education, particularly in terms of motivation and engagement (Kara et al., 2019; Knowles, 1996). The study underscored the importance of creating a supportive learning environment and maintaining clear communication to enhance student satisfaction and learning outcomes.

The implementation of the learning guide, which focused on real-world applications in Home Economics, significantly deepened PSTs' engagement with the material. The paired t-test results demonstrated a significant increase in creativity levels, rising from 2.79 to 3.84 after the learning guide implementation. These findings support the hypothesis that the design thinking approach enhances creativity, aligning with research that emphasizes its role in fostering innovative thinking and problem-solving skills (Guaman-Quintanilla et al., 2022; Hanif et al., 2019). PSTs reported that hands-on projects and collaborative efforts were instrumental in developing their creative thinking.

Moreover, PST reflections revealed a comprehensive understanding of how design thinking fosters creativity. Many noted that the structured approach of the learning guide encouraged critical thinking and collaboration, a finding consistent with research by Faregh and Amirkhizi (2023), which highlights the role of design thinking in nurturing teamwork, problem-solving, and creativity. Engaging in collaborative projects enabled PSTs not only to refine their skills but also to contribute to collective problem-solving efforts, essential competencies in today’s interconnected world.

In summary, this study provides compelling evidence that the design thinking process significantly enhances creativity in Home Economics courses, particularly in remote teaching contexts. By addressing the needs of both teachers and PSTs, the development of a structured learning guide based on design thinking principles established an effective learning framework. The findings contribute to the growing body of literature advocating for the integration of design-based STEM education in diverse disciplines, including Home Economics. Importantly, the results highlight the necessity of teacher training in innovative pedagogical approaches to ensure effective implementation. The positive impact of hands-on, practical activities on PSTs’ creativity underscores the need to adapt teaching strategies that engage PSTs in meaningful learning experiences. Moving forward, continued research and professional development opportunities will be essential for educators to leverage design thinking and foster creativity in PSTs fully. By doing so, educators can further enhance the learning experience in Home Economics and beyond, equipping future teachers with the critical skills needed for innovation and problem-solving in their professional practice.

5. Conclusion

This study provided compelling evidence that integrating design-based STEM education with design thinking in Home Economics courses significantly enhanced PSTs' creativity, even in remote learning environments. The findings were grounded in the pedagogical assumption that active, experiential learning—where students directly engage with authentic, real-world problems—fosters more profound understanding and innovative problem-solving skills. This assumption guided the development of structured training programs for teachers, systematic curriculum revisions, and the creation of immersive, technology-enhanced learning experiences. A key contribution of this study was its novel adaptation of design-based STEM learning guides for remote teaching, a field traditionally reliant on hands-on, face-to-face instruction. By incorporating collaborative mentorship, blended learning models, and continuous assessment strategies, this approach not only addressed the challenges of remote education but also bridged theory and practice in Home Economics. The implications of these findings are far-reaching. Educational institutions that adopt these innovative practices will be better equipped to navigate dynamic, technology-driven learning environments, ultimately enhancing creativity and improving learning outcomes. Additionally, this study's approach promotes ongoing professional development and action research, providing a strategic pathway for continuous curricular refinement and pedagogical innovation. Ultimately, this research contributes to the development of a more adaptive and responsive educational system—one that meets the evolving demands of 21st-century teaching and learning while fostering creativity, innovation, and practical skill development in PSTs.

6. Recommendations

Based on the study's findings and the innovative design-based STEM framework developed for Home Economics, several key recommendations are proposed to enhance remote teaching and learning. First, educational institutions should implement comprehensive teacher training programs that include structured workshops, immersive sessions, and opportunities for action research. These initiatives will help build teachers' confidence and competence in employing design thinking and innovative pedagogical strategies. Second, Home Economics curricula should be systematically revised to integrate design thinking principles, with an emphasis on real-world applications. This approach enhances content relevance for PSTs while stimulating creativity and problem-solving skills. Third, establishing mentorship programs that connect experienced educators with PSTs can foster collaborative learning environments and support teamwork. Fourth, leveraging digital tools and blended learning models can significantly enhance engagement in remote settings by providing access to interactive multimedia resources, such as video tutorials. Fifth, implementing structured feedback mechanisms and continuous assessment will help monitor student progress, allowing for timely adjustments in instructional strategies. Sixth, fostering partnerships with higher education institutions is crucial for sharing best practices, conducting joint research, and ensuring the broader dissemination of design-based STEM methodologies. Collectively, these recommendations offer a transformative pathway for preparing educators and enhancing learning outcomes in Home Economics through innovative, technology-driven, and student-centred approaches.

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