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Integrating Design Thinking in Teaching High School Physics

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Abstract. This study examined the implementation of Design Thinking (DT) in teaching high school physics through a comprehensive two-day seminar workshop. A mixed methods approach was employed to assess its effectiveness, combining quantitative and qualitative data collection and analysis. The study involved 21 pre-service teachers (PSTs) majoring in General Science from a state university in Cebu City, Cebu. The DT Framework, which comprised the following phases: Empathy, Define, Ideate, Prototype, and Test, guided the PSTs in demonstrating their teaching strategies, with the researchers evaluating their performance at each stage. Findings indicate that the Empathy phase was strengthened by effective pre-interviews, role assignments, resource availability, and structured organization. In the Define phase, PSTs successfully facilitated problem identification and encountered difficulties in guiding learners to translate questions into actionable insights. The Ideate phase encouraged creativity and collaboration, yet PSTs struggled to clarify the distinction between originality and novelty. During the Prototype phase, they promoted adaptability and resourcefulness but lacked a clear timeline for task completion. Finally, in the Test phase, while PSTs emphasized iterative improvement, they did not provide a rubric for design assessment or a structured approach to gathering end-user feedback. Overall, PSTs expressed high satisfaction with the workshop, praising the topic's relevance, the presenters' expertise, and the engaging activities. Despite these successes, recommendations include refining feedback mechanisms and incorporating a broader range of activities to enhance future workshops. This study highlights the potential of DT in enriching physics education and focuses on areas for further refinement in teacher training programs.

Keywords: Design thinking in Physics; Design thinking workshop; Pre-service teachers.

1.0 Introduction

In today's rapidly evolving world, the need for innovative, adaptive problem-solving approaches in education has never been more urgent. Design Thinking (DT), a human-centered and iterative methodology, offers a promising framework for reimagining classroom instruction by fostering empathy, creativity, and critical thinking (Malaluan & Landicho, 2022). More than a process, DT is a mindset that empowers learners to understand user needs, challenge assumptions, and develop unconventional solutions to real-world problems. Originally a practice among designers, DT has now gained traction across industries and educational institutions. Companies like Apple and Google use it to drive innovation, while universities like Stanford and Harvard have incorporated it into their curricula (Deepa, 2020). Its educational value lies in its alignment with constructivist teaching philosophies rooted in the works of Bruner (1961) and Vygotsky (1962), where learning is an active, collaborative, and reflective process.

In educational contexts, DT supports the development of key 21st-century skills such as critical thinking, collaboration, adaptability, and creative problem-solving (David Lee, 2018). Scheer and Plattner (2011) emphasize that DT phases mirror constructivist principles by facilitating meaningful engagement, self-directed learning, and metacognitive growth. A unique feature of DT is the framing of problems by students, promoting ownership and deeper reflection throughout the learning process (Melles et al., 2015). When integrated into Science and Math instruction, DT enhances conceptual understanding and nurtures empathy in STEM contexts (McCrudy et al., 2020; Painter, 2018). It also encourages differentiation and supports inclusive learning strategies (Lambert et al., 2021). However, despite its benefits, DT presents implementation challenges. Assessment is complex due to the diversity of student-generated prototypes, and aligning solutions with varied stakeholder needs can strain classroom resources (Hennessey, 2020; Diefenthaler et al., n.d.).

In teacher preparation, DT also serves as a tool for teacher growth. Educators who adopt its processes become more innovative, experimental, and collaborative (Diefenthaler et al., n.d.). However, the integration of DT must be context-sensitive, particularly in environments shaped by cultural and logistical constraints (Thoring et al., 2014; Smith et al., 2015). Despite increasing global interest, research exploring the specific application of DT in physics education remains limited. Little is known about how DT impacts pre-service teachers' (PSTs) instructional practices, reflective thinking, and satisfaction. This study addresses these gaps by implementing a DT-based seminar-workshop in physics education and examining its outcomes among PSTs.

2.0 Methodology

2.1 Research Design

The research methodology in this study adopted a mixed-methods study using both quantitative and qualitative data collection and analysis, specifically, a quasi-experimental method with a one-group posttest-only design to assess pre-service teachers' performance in using the intervention through teaching demonstration and to observe the effective integration of design thinking in lesson planning to teach physics. The study used a thematic analysis approach to thoroughly examine the qualitative data, which consists of comments made by the pre-service teachers in the workshop evaluation. This approach is employed to determine relationships and patterns of pre-service teachers' conceptions regarding the workshop seminar's overall impact on design thinking.

2.2 Research Locale

The researchers conducted the seminar at the same university for the following reasons: The university is well known for its credibility in producing globally competitive teachers. It is accredited by the Accrediting Agency of Chartered Colleges and Universities in the Philippines (AACUP) with a level IV status. Most of the researchers were graduates of the university and aimed to render their services back to their alma mater. The researchers aimed to target future educators and be trained with current and available teaching methods, rather than traditional ones.

2.3 Research Participants

The sample population was gathered from the pre-service teachers taking up a Bachelor of Secondary Education (BSEd) Major in General Science at one of the universities in Cebu City. The study used a convenience sampling non-probability design. 46 enrolled pre-service teachers were on the list, and only 21 participants were available because some pre-service teachers were assigned to their local National High School for practicum. All 21 participants were involved in the qualitative and quantitative data collection.

2.4 Research Instrument

This study used a 20-item evaluation tool in observable actions based on the 5 phases of DT. The criteria of observable actions were grouped into five phases. The empathic phase comprises interview, observation, immersion, research, and an empathy map. The first phase consisted of 9 items in total, the define phase consisted of 3 items, the ideate phase consisted of 2 items, the prototype phase consisted of 4 items, and lastly, the test phase consisted of 2 items. All items were carefully analyzed to effectively assess the quantitative performance of the pre-service teachers based on their teaching demonstrations with the application of the intervention.

This study also included a workshop evaluation tool to quantify the level of satisfaction of student interns after receiving the DT seminar-workshop. The tool is designed to assess the performance of the workshop speakers in terms of the history and definition of DT, the introduction and related literature and studies of DT, the intergenerational intervention procedures of lesson designing, and the overall workshop seminar impact. The tool also included 4 essay questions to be coded into themes for the qualitative data.

2.5 Data Gathering Procedure

Before the beginning of this study, a formal communication was sent to the school head and administration requesting permission to conduct a seminar workshop. Upon approval of the intent, the researchers created a strategic program matrix, which was proposed and then implemented. The participants signed informed consent forms to ensure proper permission in gathering the data.

This study began in March 2024 with a 20-hour duration of the seminar-workshop in 2 consecutive days. An online orientation was conducted before the seminar workshop to explain the objectives and discuss the proposed workshop overview, and informed consent was obtained. During the seminar workshop, the participants were exposed to the DT intervention as an alternative teaching method for learning physics. After the workshop, the participants were grouped into groups of five. Each team decided on varied topics to use to fit the DT intervention. Three evaluators assessed team demonstration based on each item in the observable actions. At the end of the seminar-workshop, a workshop evaluation tool was given to all participants to give feedback to the speakers and assess their performance.

This study utilized descriptive statistics to analyze both the teaching demonstration performances and the level of agreement regarding pre-service teachers' satisfaction with the seminar-workshop. The data were organized by frequency, and the mode was calculated to determine the most common level of compliance. Three evaluators assessed the performance of the teacher-demonstrators using a 5-point rating scale for each criterion. A total of 21 participants were divided into five teams, four teams with four members each and one team with five members, to collect quantitative data on the application of the demonstration teaching (DT). The same participants also provided individual data for the satisfaction rating and evaluation of the seminar-workshop and the qualitative analysis of pre-service teachers' engagement levels, regardless of their team assignments. Finally, qualitative data gathered from participant comments were thematically coded and categorized to support in-depth analysis following the completion of the seminar-workshop.

2.6 Ethical Considerations

In conducting this study, appropriate measures were taken to uphold ethical standards to ensure the protection and well-being of the participants. The following section outlines the ethical considerations that guided the design and implementation of this study. The approval letter was forwarded to the University President, Supervisor, and BSEd General Science Teacher Mentor for review and approval. The pre-service teachers were provided with detailed information regarding the study's purpose, procedures, and benefits. Informed consent was also obtained before participation, ensuring their voluntary participation agreement. They were made to understand that their decision to participate or withdraw would be respected without any repercussions. Measures were also taken to protect the confidentiality of the participants' identities and responses. Any personal information shared by the participants was kept confidential, and the data were anonymized during analysis. Data collected during the study were handled with care and integrity. All data was securely stored and accessed only by authorized personnel to maintain confidentiality and privacy. Fostering fairness and equity was also considered when selecting the participants to guarantee that the preservice teachers were all given equal opportunities to participate in the study, irrespective of individual background or attributes. The research aimed to promote the participants' professional development and pedagogical effectiveness by introducing them to innovative teaching methodologies. Efforts were made to ensure that the research process and outcomes would ultimately benefit participants and the broader educational community.

3.0 Results and Discussion

Table 1 displays the observable actions pre-service teachers took during the Empathy phase of the DT. Five items were rated as Meticulously Observed. However, Item 2 displayed the lowest rate with hardly observed descriptors. Items 5, 6, and 7 displayed no remarks. Five items out of nine were rated as Meticulously Observed, while Item 2 displayed the lowest rate with hardly observed descriptors. Three items, 5, 6, and 7, displayed no remarks and were not applicable.

Table 1. *PSTs' Observable Actions - Empathy Phase*

Subvariables	No.	Criteria/ Observable Actions	Mode	Description
Interview	1	The PSTs encouraged students to brainstorm questions.	5	Meticulously Observed
	2	The PSTs contacted and screened the end users for safety purposes.	2	Hardly Observed
Observation	3	The PSTs assigned 1-5 students per interviewee.	5	Meticulously Observed
	4	The PSTs ensured roles in the interview group.	5	Meticulously Observed
Immersion	5	The PSTs allowed students to observe end users and how they interact with their environment and activities.	-	-
	6	The PSTs encouraged the What? How? Why? (WHW) tool in observation.	-	-
	7	The PSTs allowed the students to submerge themselves into the users' experiences.	-	-
Research	8	The PSTs provided learning resources, such as books, videos, and educational games, to help students acquire knowledge and skills.	5	Meticulously Observed
Empathy map	9	The PSTs allowed the students to use a graphic organizer to organize information during empathy work.	5	Meticulously Observed

Note: (-) signifies a not applicable item, the number of items in the empathy phase

The PSTs effectively demonstrated the Empathy phase of the DT process. They encouraged learners to participate in brainstorming activities that foster creativity and critical thinking, aligning with Hennessey's (2020) and Noel and Tiu's (2016) statements. Assigning an adequate number of students to each interviewee and ensuring that every group member had distinct roles facilitated effective communication and collaboration. Additionally, providing various learning resources and allowing learners to utilize graphic organizers during the empathy phase deepened their understanding and engagement with the material, ultimately enhancing their learning experience. However, the evaluators disregarded items 5, 6, and 7 due to difficulties meeting stakeholders and safety concerns about bringing students into specific environments. The PSTs also found this immersion stage of empathy challenging to implement, which supports the statement of (Diefenthaler et al., n.d.).

The empathy phase is crucial in implementing DT. Physics teachers would find it hard to nurture the students' skills if they cannot communicate and relate to the specific problem the end-users face. PSTs ensure the technicalities in the empathy phase, but must observe their topic and plans. Moreover, in physics concepts, if students do not take note of the scientific implications of why empathy is done in the first place, the following steps will fall short, leading to a tiring repetition of DT processes. Teachers must ensure the concept aligns well with the students' interview objectives. Despite this limitation, the quantitative data for the empathic phase remained valid, as other sub-variables were considered within the nine observable actions.

Table 2 displays two items with an adequately observed rate in synthesizing end-users' needs and developing an action statement. In contrast, one item showed minimal observability in transforming problem statements into "HMW" questions. The results indicate that pre-service teachers effectively demonstrated the Define phase of the DT process by guiding learners in converting their findings into new ideas and insights and designing appropriate problem statements. This aligns with the works of Smith et al. (2015) and Diefenthaler et al. (n.d.), which emphasize the role of educators in enhancing students' capacity to become designers. However, the PSTs encountered challenges in assisting students with translating formulated problem statements into actionable questions, highlighting an area for further improvement in the Define phase.

Table 2. *PSTs' Observable Actions - Define Phase*

No.	Criteria/ Observable Actions	Mode	Description
10	The PSTs were able to guide students in synthesizing the findings into needs and insights.	4	Adequately Observed
11	The PSTs helped the students develop an actionable problem statement.	4	Adequately Observed
12	The PSTs guided the students in transforming problem statements into "how might we" (HMW) questions.	2	Hardly Observed

Physics teachers should not undermine the use of "HMW" questions, as this would showcase the ability of physics learners to think critically and transition to forming ideas to take action on the problem. The physics concepts might come in very handy because of the mathematical foundations; if physics teachers are trained enough to incorporate DT, especially in the design phase, effectively, one would not miss the opportunity to specify the needs of the end-users and consider addressing them objectively. One of the key actions in this phase for the physics teachers is to enumerate objectives for each of the problems identified.

Table 3 revealed that one item regarding collaboration was adequately observed in the pre-service teachers' performance. In contrast, the other was never observed in their actions during the Ideate phase of the DT process. The results indicate that throughout the Ideate phase, the PSTs ensured effective collaboration, demonstrating an awareness of the DT processes, particularly the importance of teamwork, as supported by Diefenthaler et al. (n.d.). However, the PSTs did not showcase originality or novelty in their ideas, suggesting a gap in their understanding of idea generation within the DT framework.

Table 3. *PSTs' Observable Actions - Ideate Phase*

No.	Criteria/ Observable Actions	Mode	Description
13	The PSTs ensured collaborative work in generating and creating ideas.	4	Adequately Observed
14	The PSTs explained that originality does not mean novelty.	1	Never Observed

Ideas form in many ways, primarily how students address the known problem. Physics teachers must scaffold students in forming ideas and ask questions when a plan is crafted. The teacher must ensure that there is collaboration within the group, and they must do a self-evaluation of the plans created. Students should also be reminded to suggest ways that would be very feasible and applicable in reality, as one wanting to create an original might end up overcomplicating the design for the sake of novelty.

The data in Table 4 displayed positive results in most aspects of the Prototype phase, particularly in allowing time for prototype adjustments, accepting model imperfections, and encouraging the use of locally available materials, all of which were meticulously observed. The results indicate that pre-service teachers effectively demonstrated the Prototype phase, aligning with the findings of Smith et al. (2015) and Cassim (2009), who emphasize that engaging in a nonlinear, action-based experience with real-world problems fosters critical thinking and enhances learners' ability to become designers. However, setting a deadline for prototyping was hardly observed. This makes the Prototype phase one of the most critical and challenging stages, allowing students to explore various models and solutions. Setting deadlines remains essential for successfully conducting this phase. To effectively address end-user needs, prototypes should be developed within structured timelines. As Diefenthaler et al. (n.d.) suggest, limited resources and student constraints can impact the strict enforcement of deadlines.

Table 4. *PSTs' Observable Actions - Prototype Phase*

No.	Criteria/ Observable Actions	Mode	Description
15	The PSTs set deadlines for prototyping.	2	Hardly Observed
16	The PSTs could allot time for the necessary adjustments for the prototype.	5	Meticulously Observed
17	The PSTs reiterated that models do not have to be perfect.	5	Meticulously Observed
18	The PSTs encouraged the students to use locally available materials.	5	Meticulously Observed

The failure of most PSTs to set or assign deadlines for prototyping is related to the criteria or observable actions that are never observed in the subsequent Design Thinking phase. The prioritization of prototype development has allowed PSTs to allocate resources and attention towards the development of the prototype itself. Consequently, setting deadlines was inadvertently overlooked. While this approach allowed for the creation of quality prototypes, it also left a gap in the supposed structured timeline of the design thinking process. Failure to set deadlines can significantly impact the progression of the instructional process, as delays in one stage or phase inevitably affect the timeline and quality of the succeeding, equally important phases.

The data in Table 5 revealed that Items 19 and 20 were never observed in the actions taken by the PSTs during the Test phase of the DT process. Specifically, there was an absence of a designed rubric or criteria for prototype assessment and a meeting with end-users for testing. This lack of assessment criteria highlights a limitation in the PSTs' understanding of the role of evaluation in prototype development. Additionally, failing to engage end-users in the testing phase resulted in a missed opportunity to gather feedback for improving the prototype design.

Table 5. *PSTs' Observable Actions - Test Phase*

No.	Criteria/ Observable Actions	Mode	Description
19	The PSTs designed a rubric or criteria for prototype assessment.	1	Never observed
20	The PSTs set a meeting with the end-users for testing.	1	Never observed

According to the PSTs, these criteria or observable actions for the test phase were never observed in the demonstration of Design Thinking instruction because the PSTs wanted to streamline the development process to meet stringent time constraints. Because they chose to streamline the process, they optimized the design phase and left the test phase with lower priority. These findings suggest a gap in the PSTs' application of the Test phase, which is essential for refining and validating design solutions.

The evaluation results from 21 participants provide valuable insights into the overall satisfaction levels of pre-service teachers regarding the seminar speakers' performance in a comprehensive seminar-workshop (see Table 6). The speakers received predominantly positive ratings across various aspects, including clarity of communication, meeting workshop objectives, preparation, engagement, relevance of topics, organization of content, usefulness in work, facilitator knowledge, and adequacy of time and facilities. Participants largely agreed that the workshop objectives were clearly defined, met, and well-prepared, and they found the sessions engaging, organized, and easy to follow. However, some areas, such as the relevance of topics and distribution of materials, received mixed feedback. Overall, these findings highlight the effectiveness of the seminar speakers in delivering an informative and engaging experience while also identifying areas for improvement to enhance the learning experience for pre-service teachers further.

Table 6. *Pre-service Teachers' Satisfaction Rate in Frequency based on the Performance of the Speakers in the Overall Seminar-Workshop*

Statement of Performance	Level of Agreement and the Frequency per Statement				
	1	2	3	4	5
The objectives of the workshop were clearly defined.				2	19
The workshop objectives were met.				2	19
The workshop was well prepared.				2	19
The workshop was engaging.				2	19
The topics covered were relevant to me.				1	20
The content was organized and easy to follow.				2	19
Participation and interaction were encouraged.					21
The materials distributed were helpful.					21
This workshop experience will be helpful in my work.				1	20
The facilitators were knowledgeable about the workshop topics.					21
The time allotted for the training was sufficient.					21
The meeting room and facilities were adequate and comfortable.					21

The thematic map of pre-service teachers' engagement levels in seminar workshops using Design Thinking highlights key aspects of their experience (see Table 7). Participants noted several positive aspects, including knowledgeable presenters who were responsive to interns' needs, engaging activities that enhanced social skills and critical thinking, and relevant content that made the workshop informative and meaningful, which supports the study of Westover (2025). However, areas for improvement were also identified, such as the need for better feedback mechanisms emphasized in the study of Tariq et al. (2019), more precise instructions as stated by Andrew et al. (2024), and a greater diversity of activities, particularly more sample demonstrations to illustrate classroom applications. The workshop also influenced participants' teaching practices, with many expressing plans to integrate Design Thinking into lesson planning to foster curiosity and higher-order thinking skills. Some participants reported behavioral changes, such as a commitment to expanding their teaching methods and a stronger connection with students.

Table 7. *Thematic Map of Pre-service Teachers' Engagement Levels in Seminar Workshops Using Design Thinking*

Theme	Subtheme	Sample Quote
Positive Aspects of the Workshop	Knowledgeable Presenters	"*The speakers. They are all responsive to the needs and queries of the interns.*"
	Engaging Activities	"*The workshop is very engaging and informative. I learned so many things, which enhance my social skills and critical thinking.*"
	Relevance of Content	"*The workshop is very engaging and informative. I learned so many things, which enhance my social skills and critical thinking.*"
Areas for Workshop Improvement	Suggestions for Enhancements	"*Probably the only part of the workshop that we all agreed upon that needs improvement is the feedback part.*"
	Clarification Needed	"*Clear instructions.*"
	Diversity of Activities	"*I think their sample demonstration was well delivered and done, and we need more of it to show how it is done in the classroom setting.*"
Changes in Practice Resulting from the Workshop	Implementation Plans	"*I would like to keep this approach at lesson planning since it is excellent at stimulating the students' curiosity and higher-order thinking skills. Furthermore, it gives students purposeful activities as they could see with real-world scenarios.*"
	Behavioral Changes	"*To broaden my knowledge and to never limit the methods in conducting the class/presenting the topics*".
	Perceived Impact	*“There are a lot of ideas and strategies that I have learned in this seminar-workshop. I learned how to connect with my students.”*
Overall Evaluation of the Workshop	Satisfaction Levels	*Goals were achieved, and a good rapport was established. Therefore, I can say that this training/workshop is satisfactory.*"
	Learning Outcomes	"*I was finally able to understand what D.T. is, and I might be considering (using) it in my future lesson plans.*"
	Suggestions for Future Workshops	"*The overall workshop is fun, and I would like my other classmates who are currently having their off-campus to experience the workshop and seminar.*"

Overall, the seminar-workshop was well-received by the PSTs, who found the sessions insightful and highly relevant to their future instructional practices. The Design Thinking strategy in teaching high school Physics provided practical pedagogical solutions to common classroom problems and offered innovative approaches to enhance student engagement and learning outcomes. As a result, many PSTs expressed strong interest in incorporating the newly learned strategy into their teaching, recognizing their potential to improve the delivery of the Physics curriculum and student achievement.

4.0 Conclusion

Integrating Design Thinking (DT) into lesson planning for high school physics has shown clear educational benefits, as demonstrated by the findings of this study. Focusing on pre-service teachers (PSTs), the research highlighted how DT fosters empathy, creativity, collaboration, and critical thinking skills crucial for effective science instruction. The seminar-workshop offered a supportive and engaging environment where PSTs could move beyond abstract pedagogical theories and experience realistic, hands-on teaching practices. Many participants reported high satisfaction levels, describing the workshop as memorable and transformative.

Several recommendations are proposed for future research and implementation to build on these positive outcomes. First, the sample size should be expanded by including a more diverse group of PSTs from multiple institutions to improve the generalizability of the results. Extending the duration of the study would also allow for a deeper understanding of how DT is applied over time, particularly as participants transition into full-time teaching roles. Adopting a more robust mixed-methods approach—combining quantitative and qualitative data—could offer richer insights into how participants internalize and apply DT principles.

Moreover, the development and validation of more comprehensive assessment tools are necessary. This includes refining the DT evaluation tool used during workshops and creating an end-user rubric to assess prototypes during testing. Enhanced statistical analysis should also be employed to identify significant patterns and relationships in the data. A follow-up study is recommended to evaluate long-term retention and continued use of DT in classroom practice.

Future researchers are encouraged to explore additional physics topics and subject areas where DT may be applicable and settings where its integration might be limited. In parallel, educators should create opportunities for students to engage in community-based problem-solving, using DT as a framework to generate diverse and practical solutions. Finally, academic administrators should promote intuitive, action-based learning by embedding performance tasks in the curriculum, cultivating critical thinking, adaptability, and learner agency.

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