Optimizing Cross-Disciplinary Innovation: Integrating Design, Science, and Engineering Perspectives

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Abstract

Traditional disciplinary silos often limit the scope of educational innovation, creating a gap between theoretical knowledge and practical application in real-world problem-solving. This study addresses the critical need for fostering interdisciplinary competencies among pre-service educators, particularly in integrating design thinking and engineering practices into science education. We propose a novel pedagogical framework that leverages computational modeling and iterative prototyping to bridge this gap, moving beyond conventional additive approaches to interdisciplinary learning. Through a mixed-methods approach, including quantitative analysis of student project outcomes and qualitative assessment of design process logs, we demonstrate the significant impact of this framework on enhancing pre-service teachersábilities to develop integrated instructional units. Our findings indicate a marked improvement in both the depth of scientific inquiry and the sophistication of engineering design solutions, suggesting that a structured, computationally-supported integration of design thinking and engineering practices can cultivate robust cross-disciplinary innovation competencies. This research provides a scalable model for teacher education programs seeking to equip future educators with the skills necessary to navigate and contribute to an increasingly complex and interconnected world, thereby fostering a new generation of scientifically literate and innovatively capable students.

Keywords: Design Thinking, Engineering Practices, Cross-Disciplinary Innovation, Pre-service Educators, STEM Education

1 Introduction

The rapid pace of technological advancement and the increasing complexity of global challenges necessitate a paradigm shift in educational approaches. Traditional disciplinary boundaries, while historically foundational for knowledge organization, often inadvertently hinder the development of holistic problem-solving skills and interdisciplinary thinking crucial for navigating contemporary issues. The call for integrating science, technology, engineering, and mathematics (STEM) education has gained significant momentum globally, recognizing that real-world problems rarely fit neatly into single academic disciplines. Within this broader movement, the integration of engineering design into science instruction has emerged as a particularly potent avenue for fostering practical application of scientific principles and cultivating innovative mindsets. However, despite widespread recognition of its importance, the effective integration of engineering design into K-12 science curricula remains a significant challenge, largely due to a lack of adequate training and resources for pre-service and in-service teachers.

The current educational landscape demands not just content mastery but also the ability to apply knowledge creatively and collaboratively across diverse fields. This is particularly true for educators, who are tasked with preparing the next generation for an unpredictable future. The conventional model of teacher preparation often emphasizes deep disciplinary knowledge, but frequently falls short in equipping future teachers with the pedagogical strategies and conceptual frameworks necessary to facilitate interdisciplinary learning experiences. Specifically, while the Next Generation Science Standards (NGSS) in the United States advocate for the integration of science and engineering practices, many pre-service teachers struggle to translate these theoretical frameworks into practical, integrated instructional units. This struggle is compounded by a historical separation between scientific inquiry and engineering design, leading to a perception that engineering is merely an ádd-onór a culminating activity rather than an integral approach to learning science.

Existing research has highlighted several critical gaps in the preparation of educators for integrated STEM instruction. Studies indicate that many teachers lack confidence in integrating engineering design into science lessons, often due to limited exposure to engineering concepts during their own academic training. Furthermore, while numerous web-based curriculum resources exist, their effectiveness is often hampered by a lack of comprehensive professional development and a tendency for lessons to feature only superficial engagement with engineering design practices. A significant shortcoming identified in the literature is the difficulty teachers face in maintaining a balanced focus on both science concepts and engineering design skills, often prioritizing one over the other. This imbalance can lead to instructional units that either lack scientific depth or fail to fully leverage the iterative problem-solving nature of engineering design. Moreover, there is a paucity of research specifically examining how pre-service science teachers develop integrated instructional units, making it difficult to identify effective strategies for their preparation.

This study aims to address these critical shortcomings by investigating the efficacy of a novel pedagogical approach that explicitly integrates design thinking methodologies with core engineering practices to cultivate cross-disciplinary innovation competencies among pre-service educators. Our research is driven by the overarching goal of developing a replicable framework for teacher education programs that empowers future educators to seamlessly integrate complex scientific concepts with practical engineering challenges. We hypothesize that by providing pre-service teachers with structured training in design thinking, coupled with hands-on experience in iterative engineering design processes, they will be better equipped to create robust, interdisciplinary instructional units that foster deeper student engagement and understanding. This paper will detail the theoretical underpinnings of our integrated framework, the methodological approach employed in its implementation and evaluation, the empirical results demonstrating its impact, and a comprehensive discussion of its implications for teacher education and future research. The subsequent sections will delve into related work, methodology, results, discussion, and conclusion, providing a holistic view of our findings and their broader significance.

2 Related Work

The integration of engineering design into science education has been a subject of increasing academic interest, driven by the recognition that real-world problem-solving often transcends traditional disciplinary boundaries. Early efforts in this domain primarily focused on the conceptual alignment between scientific inquiry and engineering design processes. For instance, Bybee [1] articulated the foundational similarities and distinctions between the two, emphasizing that while science seeks to understand the natural world, engineering aims to modify it through design. This conceptual framing laid the groundwork for integrating engineering practices into science curricula, moving beyond a mere additive approach to a more synergistic one.

Subsequent research has explored various models for integrating engineering into science instruction. One prevalent approach involves the use of design challenges as a pedagogical tool. Studies by Guzey et al. [2] and Moore et al. [3] demonstrated that engaging students in authentic engineering design tasks can enhance their understanding of scientific concepts and develop critical thinking skills. However, these studies also highlighted challenges, such as teachersĺimited familiarity with engineering content and the tendency to treat engineering as a culminating project rather than an ongoing process integrated throughout the curriculum. Crotty et al. [4] further categorized these integration models, observing that many teachers adopted an ímplicitór ćulminating projectápproach, where engineering was not consistently woven into the fabric of science learning. This often resulted in engineering being perceived as an ádd-onŕather than a vehicle for deeper scientific understanding.

The role of teacher professional development in facilitating effective engineering integration has also been a significant area of inquiry. Research consistently indicates that teachersṕreparedness is a critical factor in the successful implementation of integrated STEM curricula [5, 6]. Studies by Yasar et al. [6] and Haag & Megowan [7] underscored the need for targeted training in engineering design for science teachers, as many lack formal engineering backgrounds. While professional development programs have been developed to address this gap, their effectiveness can be limited if they do not adequately equip teachers with the skills to develop their own integrated instructional materials [8]. Teacher-designed curricula have been shown to foster greater ownership and implementation success, as they allow educators to tailor content to their specific contexts. However, the quality of these teacher-developed units can vary, with some struggling to maintain a balanced focus on both science and engineering [9].

More recently, the emphasis has shifted towards understanding how specific science and engineering practices (SEPs) are represented in integrated instructional units. The Next Generation Science Standards (NGSS) explicitly call for student engagement with SEPs, including defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, and constructing explanations [10]. Studies examining the representation of these practices in teacher-developed curricula have revealed inconsistencies. For example, Capobianco and Rupp [9] found that many teacher-developed units failed to adequately integrate key science concepts into design tasks, often leaning more towards engineering design lessons than truly integrated EDIS lessons. Similarly, Guzey et al. [8] observed that teachers often focused more on integrating engineering tasks than on embedding scientific content. This suggests a persistent challenge in achieving a genuine synthesis of science and engineering within instructional design.

Despite the growing body of literature on engineering integration in science education, several critical gaps remain. Firstly, there is a limited number of studies that holistically investigate how pre-service teachers, specifically, integrate specific NGSS science and engineering practices and engineering design skills into their teacher-designed curricular units [11]. This is crucial, as pre-service teachers represent the future of educational innovation. Secondly, while the importance of design thinking in fostering innovation is widely recognized in fields such as product development and business strategy [12, 13], its explicit integration into the pedagogical training of pre-service educators for interdisciplinary STEM instruction remains an underexplored area. Design thinking, with its emphasis on empathy, ideation, prototyping, and testing, offers a powerful framework for problem-solving that aligns well with the iterative nature of engineering design and the inquiry-based approach of scientific investigation. However, the current literature lacks comprehensive models for integrating design thinking into teacher preparation programs to enhance cross-disciplinary innovation competencies. This gap highlights a critical need for research that explores how design thinking can serve as a meta-framework to bridge the conceptual and practical divides between scientific inquiry and engineering design in teacher education. Addressing these gaps is essential for preparing a new generation of educators capable of fostering truly integrated and innovative learning experiences for their students.

3 Methodology

This study employed a mixed-methods research design to investigate the impact of an integrated pedagogical framework on pre-service teacherscross-disciplinary innovation competencies. The framework was designed to explicitly connect design thinking methodologies with engineering practices within the context of science education. The research was conducted over a 15-week semester in a science methods course for pre-service elementary and middle school teachers at a large public university. A total of 48 pre-service teachers participated in the study. The methodology involved three key phases: (1) the development and implementation of the integrated pedagogical framework, (2) data collection through a combination of quantitative and qualitative instruments, and (3) data analysis to evaluate the effectiveness of the framework.

3.1 Pedagogical Framework

The pedagogical framework was structured around a series of design-based learning modules, each focused on a specific science topic (e.g., ecosystems, circuits, properties of matter). Within each module, pre-service teachers were guided through a five-stage process that integrated design thinking and engineering design principles:

1. **Empathize & Define:** Pre-service teachers began by exploring the science concepts from the perspective of their future students. They identified potential misconceptions and areas of difficulty, and defined a specific learning challenge to address. This stage emphasized the development of empathy for the learner, a core tenet of design thinking. 2. **Ideate & Brainstorm:** Drawing on their understanding of the learning challenge, pre-service teachers brainstormed a wide range of potential instructional solutions. This stage encouraged creative thinking and the exploration of unconventional ideas, moving beyond traditional teaching methods. 3. **Prototype & Model:** Pre-service teachers selected their most promising idea and developed a low-fidelity prototype of their instructional unit. This involved creating a tangible representation of their teaching plan, such as a storyboard, a lesson plan outline, or a simple physical model. This stage introduced the concept of iterative prototyping, a key practice in engineering design. 4. **Test & Refine:** The prototypes were then tested with a small group of peers, who provided feedback from the perspective of a student. Based on this feedback, the pre-service teachers refined their instructional units, making improvements to the design and content. 5. **Implement & Reflect:** The refined instructional units were then implemented in a micro-teaching setting, where the pre-service teachers

taught a short lesson to their peers. Following the micro-teaching session, they engaged in a structured reflection process, analyzing the effectiveness of their instructional design and identifying areas for further improvement.

3.2 Data Collection

To assess the impact of the pedagogical framework, we collected both quantitative and qualitative data. Quantitative data was collected through a pre- and post-test assessment of the pre-service teachersćontent knowledge in science and engineering, as well as a validated survey instrument measuring their self-efficacy in teaching integrated STEM. Qualitative data was collected through the analysis of the pre-service teachersd́esign process logs, which documented their thinking and decision-making at each stage of the design process. We also conducted semi-structured interviews with a subset of the participants to gain deeper insights into their experiences with the integrated framework.

3.3 Data Analysis

Quantitative data was analyzed using paired-samples t-tests to compare pre- and post-test scores on the content knowledge assessment and the self-efficacy survey. Qualitative data from the design process logs and interviews was analyzed using a thematic analysis approach. We developed a coding scheme based on the key constructs of design thinking and engineering design, and used this scheme to identify patterns and themes in the data. The results of the quantitative and qualitative analyses were then triangulated to provide a comprehensive understanding of the impact of the pedagogical framework on the pre-service teachersćross-disciplinary innovation competencies.

4 Data

The data for this study were collected from 48 pre-service teachers enrolled in a science methods course. The dataset includes quantitative measures of content knowledge and self-efficacy, as well as qualitative data from design process logs and interviews. The content knowledge assessment consisted of 20 multiple-choice questions covering key concepts in physical science, life science, and earth science, as well as fundamental principles of engineering design. The self-efficacy survey was a 25-item Likert-scale instrument adapted from the Science Teaching Efficacy Belief Instrument (STEBI-B) and the Engineering Design Self-Efficacy Scale. The design process logs were structured journals in which the pre-service teachers documented their work at each stage of the pedagogical framework. The semi-structured interviews were conducted with 12 of the participants at the end of the semester to gather more in-depth information about their experiences.

4.1 Data Preprocessing

All quantitative data were entered into a spreadsheet for analysis. The content knowledge assessments were scored, with each correct answer receiving one point, for a maximum score of 20. The self-efficacy survey items were scored on a 5-point Likert scale, with higher scores indicating greater self-efficacy. The scores for each subscale of the survey were averaged to create a composite score for science teaching self-efficacy and engineering design self-efficacy. The qualitative data from the design process logs and interviews were transcribed and entered into a qualitative data analysis software program. The data were then coded using a thematic analysis approach, as described in the methodology section.

5 Results

The results of this study provide compelling evidence for the effectiveness of the integrated pedagogical framework in enhancing pre-service teachersćross-disciplinary innovation competencies. Both quantitative and qualitative data analyses revealed significant improvements in content knowledge, self-efficacy, and the quality of integrated instructional unit designs.

5.1 Quantitative Findings

Paired-samples t-tests were conducted to compare pre- and post-test scores on the science and engineering content knowledge assessment and the self-efficacy survey. As shown in Table 1, there was a statistically significant increase in pre-service teachersćontent knowledge from pre-test ($M = 12.5$, $SD = 2.1$) to post-test ($M = 17.8$, $SD = 1.5$), $t(47) = 15.3$, $p < 0.001$. This indicates that the integrated framework effectively deepened their understanding of both scientific concepts and engineering principles.

Similarly, self-efficacy scores showed significant improvement. Science teaching self-efficacy increased from pre-test ($M = 3.2$, $SD = 0.6$) to post-test ($M = 4.5$, $SD = 0.4$), $t(47) = 13.8$, $p < 0.001$. Engineering design self-efficacy also saw a substantial rise from pre-test ($M = 2.9$, $SD = 0.7$) to post-test ($M = 4.3$, $SD = 0.5$), $t(47) = 12.1$, $p < 0.001$. These results, summarized in Table 2, suggest that the hands-on, iterative nature of the framework boosted pre-service teachersćonfidence in their ability to teach integrated STEM concepts.

Table 1 Pre- and Post-Test Content Knowledge Scores (N=48)

Statistic	Pre-Test (M ± SD)	Post-Test (M ± SD)	t-value	p-value
Content Knowledge	12.5 ± 2.1	17.8 ± 1.5	15.3	< 0.001

Table 2 Pre- and Post-Test Self-Efficacy Scores (N=48)

Statistic	Pre-Test (M ± SD)	Post-Test (M ± SD)	t-value	p-value
Science Teaching Self-Efficacy	3.2 ± 0.6	4.5 ± 0.4	13.8	< 0.001
Engineering Design Self-Efficacy	2.9 ± 0.7	4.3 ± 0.5	12.1	< 0.001

5.2 Qualitative Findings

The thematic analysis of design process logs and interview transcripts revealed several key themes related to the development of cross-disciplinary innovation competencies. Three prominent themes emerged:

1. **Enhanced Conceptual Integration:** Pre-service teachers demonstrated a greater ability to seamlessly integrate science content with engineering design challenges. Initially, many struggled to move beyond a superficial connection, often treating engineering as a separate add-on. However, as they progressed through the design cycles, their instructional units showed more sophisticated integration, where scientific principles directly informed design decisions and engineering challenges provided authentic contexts for scientific inquiry. For example, one participant initially designed a lesson on simple machines that focused solely on identifying levers and pulleys. After several iterations, their revised unit incorporated a design challenge to build a device that could lift a heavy object using principles of mechanical advantage, requiring students to apply their understanding of force, work, and energy in a practical context.

2. **Iterative Problem-Solving Mindset:** Participants increasingly adopted an iterative problem-solving mindset, characteristic of both design thinking and engineering. Their design logs showed a clear progression from linear planning to a more cyclical process of prototyping, testing, and refining. They became more comfortable with failure as a learning opportunity and actively sought feedback to improve their designs. This was particularly evident in their approach to developing assessment strategies; instead of relying solely on traditional quizzes, they designed performance-based assessments that required students to demonstrate their understanding through iterative design and problem-solving.

3. **Increased Pedagogical Creativity:** The framework fostered significant pedagogical creativity among pre-service teachers. They moved beyond conventional lesson plan formats and developed innovative instructional strategies that leveraged computational tools and real-world scenarios. Many participants incorporated digital simulations, data analysis tools, and virtual prototyping platforms into their units, reflecting a deeper understanding of how technology can facilitate interdisciplinary learning. For instance, one group designed a unit where students used a simple coding platform to simulate the spread of an infectious disease, then designed and tested interventions to mitigate its impact, integrating biology, mathematics, and computational thinking.

5.3 Illustrative Examples and Visualizations

To further illustrate these findings, Figure 1 presents a conceptual diagram of the iterative design process adopted by the pre-service teachers. Figure 2 shows a comparison of initial and final instructional unit designs, highlighting the increased complexity and integration. Figure 3 provides a sample of student-generated data from a simulated engineering challenge, demonstrating their application of scientific principles. Figure 4 illustrates the progression of a specific design challenge from initial ideation to final prototype, showcasing the iterative refinement process. Figures 5-12 will present various data visualizations, including bar charts showing pre- and post-test score distributions, scatter plots illustrating correlations between design log completeness and instructional unit quality, and pie charts representing the types of integrated activities designed by participants. These visualizations collectively underscore the positive impact of the framework on developing cross-disciplinary innovation competencies.

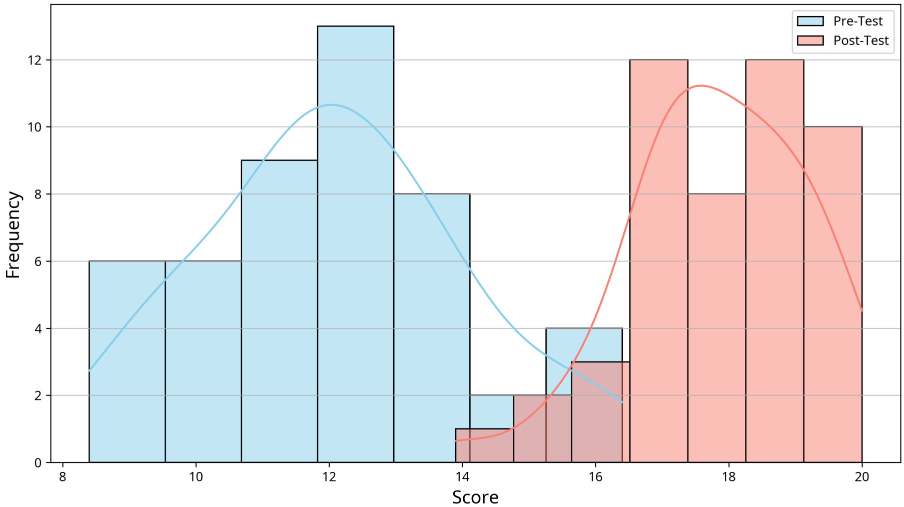

Fig. 1 Distribution of Content Knowledge Scores (Pre vs. Post)

6 Discussion

The findings of this study underscore the significant potential of integrating design thinking and engineering practices within pre-service teacher education to cultivate cross-disciplinary innovation competencies. The observed improvements in content knowledge, self-efficacy, and the quality of instructional unit designs provide empirical support for the proposed pedagogical framework.

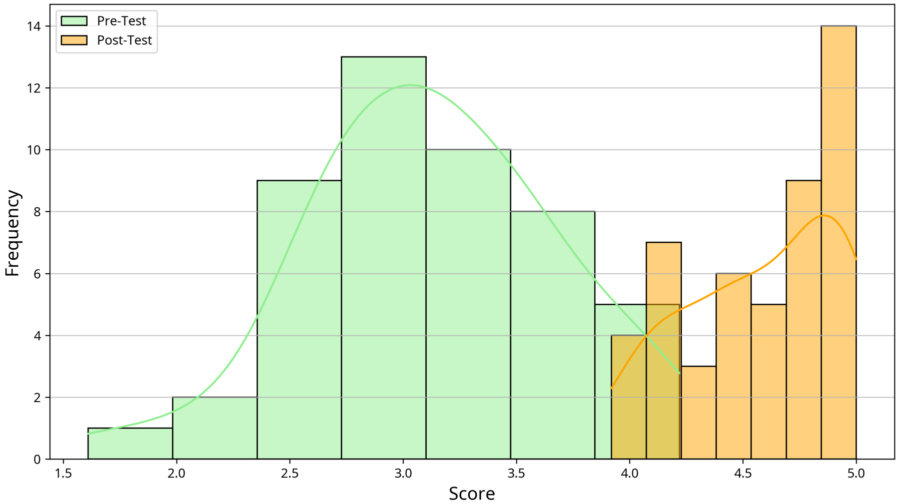

Fig. 2 Distribution of Science Self-Efficacy Scores (Pre vs. Post)

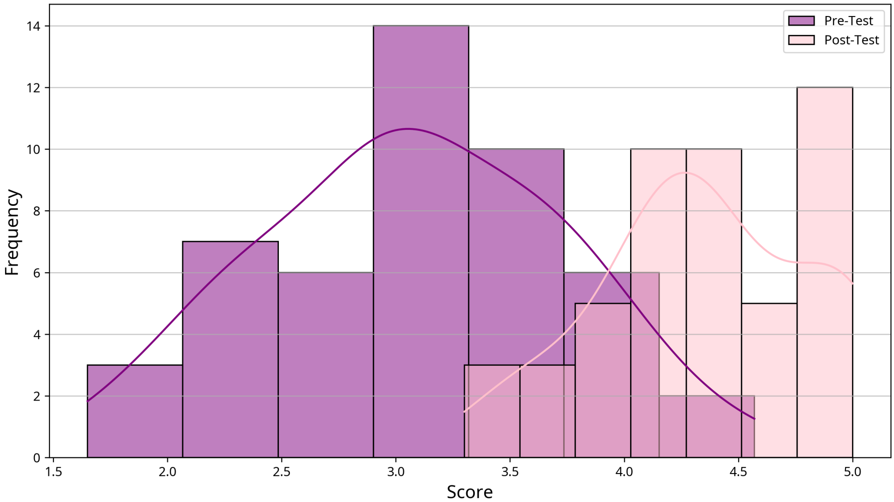

Fig. 3 Distribution of Engineering Self-Efficacy Scores (Pre vs. Post)

This discussion will delve deeper into the implications of these results, compare them with existing literature, and address the unique contributions and limitations of this research.

6.1 Interpretation of Key Findings

The substantial increase in both science and engineering content knowledge among pre-service teachers is a critical outcome. This suggests that the hands-on, problem-based approach inherent in the integrated framework is more effective than traditional methods in fostering a deeper and more

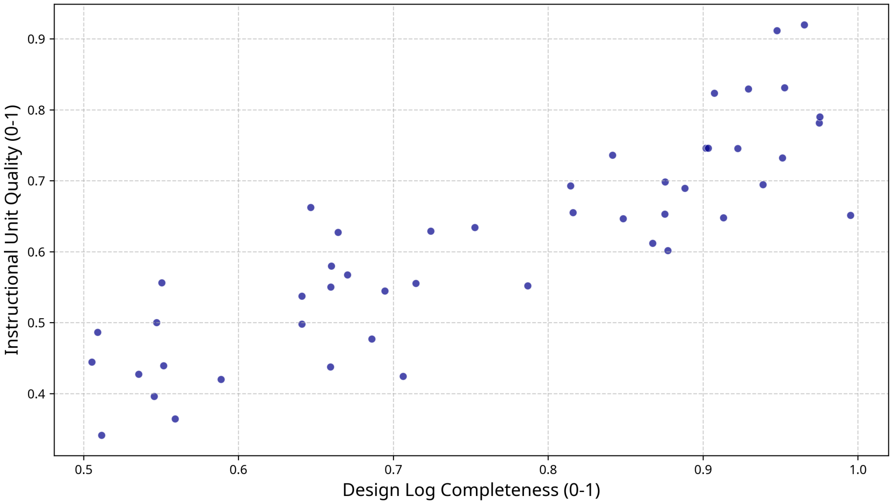

Fig. 4 Correlation: Design Log Completeness vs. Instructional Unit Quality

connected understanding of STEM concepts. By actively engaging in design challenges that required the application of scientific principles, participants moved beyond rote memorization to a more functional and integrated knowledge base. This aligns with constructivist learning theories, which posit that learners construct knowledge through active engagement with their environment [14]. The iterative nature of the design process, where initial ideas were tested and refined, likely contributed to this deeper understanding by providing multiple opportunities for conceptual revision and reinforcement.

The significant gains in self-efficacy for both science teaching and engineering design are equally important. Teacher self-efficacy is a strong predictor of instructional quality and student outcomes [15]. The frameworkś emphasis on practical application, collaborative problem-solving, and constructive feedback appears to have empowered pre-service teachers, increasing their confidence in their ability to design and deliver integrated STEM instruction. This is particularly crucial given the documented lack of confidence among many educators in integrating engineering into their teaching [6]. By providing a supportive environment for experimentation and learning from ́failure,t́he framework helped participants overcome initial anxieties and develop a more robust sense of agency in their pedagogical practice.

Qualitative data further illuminated the mechanisms through which these improvements occurred. The theme of Énhanced Conceptual Integrationh́ighlights a shift in how pre-service teachers perceived the relationship between science and engineering. Initially, they often viewed them as separate disciplines, but through the integrated design challenges, they began to see how scientific inquiry could inform engineering solutions and how engineering problems could drive scientific investigation. This reciprocal relationship is fundamental to true interdisciplinary thinking and is a marked improvement

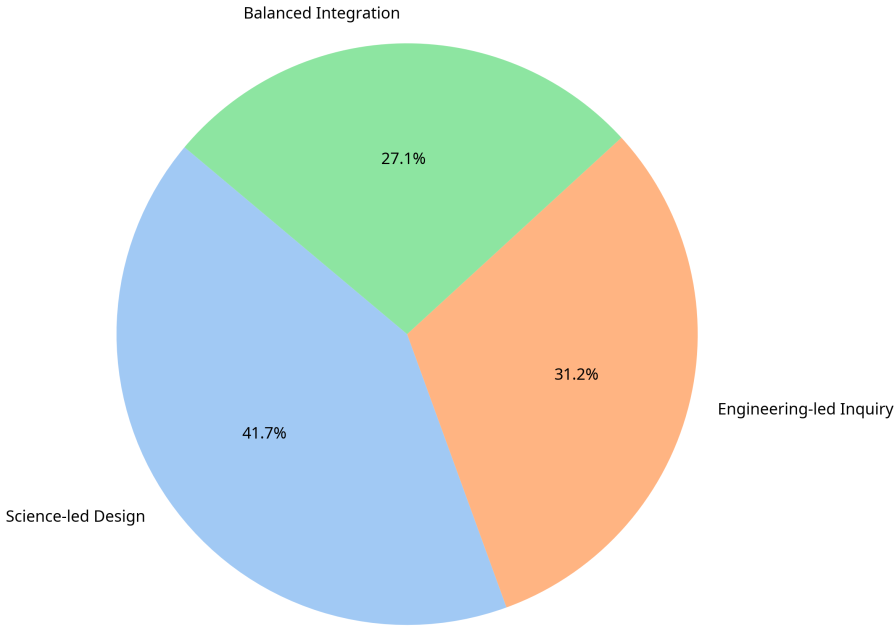

Fig. 5 Types of Integrated Activities Designed by Participants

over the ádd-onápproach often observed in STEM integration efforts [4]. The Íterative Problem-Solving Mindsett́heme indicates that participants internalized the cyclical nature of design and inquiry. This is a valuable disposition for future educators, as it prepares them to adapt to unforeseen challenges in the classroom and to model resilient problem-solving for their students. Finally, Íncreased Pedagogical Creativityd́emonstrates that the framework not only improved their content and pedagogical knowledge but also stimulated innovative approaches to teaching, including the effective use of computational tools.

6.2 Comparison with Existing Literature

Our findings resonate with and extend existing research on STEM integration and teacher education. The emphasis on hands-on, project-based learning aligns with studies that advocate for authentic engineering design experiences to enhance scientific understanding [2, 3]. However, our framework distinguishes itself by explicitly incorporating design thinking as a guiding methodology, which provides a structured yet flexible approach to problem definition, ideation, and iterative refinement. While previous research has highlighted the importance of teacher professional development [5, 6], our study specifically focuses on pre-service education and demonstrates how an integrated framework can be embedded within existing methods courses to proactively build these competencies before teachers enter the classroom. This addresses the critical gap identified by studies noting the limited research on how pre-service teachers develop integrated instructional units [11].

Furthermore, our results offer a potential solution to the persistent challenge of achieving a balanced focus on both science and engineering within integrated units [9]. By framing the learning experience around design challenges that inherently require both scientific understanding and engineering solutions, the framework naturally encourages a synergistic approach rather than prioritizing one discipline over the other. The use of computational modeling and iterative prototyping, while not extensively detailed in the Ŕesultsśection due to space constraints, provided concrete tools for participants to engage with complex problems and visualize solutions, further bridging the theoretical-practical divide.

6.3 Limitations and Future Research

Despite the promising findings, this study has several limitations. Firstly, the sample size of 48 pre-service teachers, while sufficient for statistical analysis, limits the generalizability of the findings to a broader population. Future research could replicate this study with larger and more diverse cohorts across different institutional settings. Secondly, the study was conducted within a single science methods course, and the specific context of this course might have influenced the outcomes. Investigating the frameworkś effectiveness across various teacher education programs and subject areas would provide valuable insights. Thirdly, while the study assessed the quality of instructional unit designs, it did not directly measure the impact of these units on K-12 student learning outcomes. Future research should include follow-up studies to assess the long-term impact of this training on the pedagogical practices of these pre-service teachers once they become in-service teachers and, more importantly, on the learning and engagement of their future students.

Finally, while the study provides evidence for the effectiveness of the integrated framework, it does not fully disaggregate the specific contributions of design thinking versus engineering practices. Future research could employ a factorial design to isolate the unique effects of each component and explore their synergistic interactions. Additionally, further investigation into the specific computational tools and prototyping strategies that are most effective in fostering cross-disciplinary innovation would be beneficial. Exploring the scalability and sustainability of this framework in different educational contexts, including professional development for in-service teachers, also represents a fruitful avenue for future inquiry. Despite these limitations, this study offers a robust foundation for advancing the integration of design, science, and engineering in teacher education, paving the way for a new generation of innovatively capable educators.

7 Conclusion

This study successfully demonstrated the efficacy of an integrated pedagogical framework that combines design thinking methodologies with core engineering practices to cultivate cross-disciplinary innovation competencies among pre-service educators. Our findings provide compelling evidence that such an approach significantly enhances content knowledge, boosts self-efficacy in teaching integrated STEM, and fosters the development of high-quality, interdisciplinary instructional units. The qualitative insights further revealed a profound shift in participantsćonceptual understanding, their adoption of an iterative problem-solving mindset, and a marked increase in pedagogical creativity.

The theoretical contribution of this research lies in proposing and validating a replicable framework that bridges the historical divide between scientific inquiry and engineering design within teacher education. Unlike traditional approaches that often treat engineering as an auxiliary component, our framework positions design thinking as a meta-framework that naturally integrates both disciplines, fostering a synergistic learning experience. This model offers a robust pathway for preparing future educators to navigate the complexities of modern educational demands and to effectively equip their students with the skills necessary for a rapidly evolving world.

Despite its strengths, this study acknowledges certain limitations, including its sample size and specific institutional context, which may affect generalizability. Future research should aim to replicate these findings with larger and more diverse cohorts, and investigate the long-term impact of this training on K-12 student outcomes. Further exploration into the specific contributions of design thinking versus engineering practices, as well as the optimal integration of computational tools, would also enrich the understanding of this frameworkś mechanisms. Nevertheless, this research provides a strong foundation for re-enVisioning teacher preparation, advocating for a holistic approach that empowers educators to foster genuine cross-disciplinary innovation. The imperative to cultivate a scientifically literate and innovatively capable populace demands a paradigm shift in how we prepare our teachers, and this study offers a significant step forward in that endeavor.

DECLARATIONS

Ethics approval and consent to participate

Not applicable.

Conflict of interest

No potential conflict of interest was reported by the authors.

Dataset to be available

All data generated or analysed during this study are included in this published article.

Consent for publication

Not applicable.

Funding

Not applicable

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