OPEN ACCESS
Journal of Loomingulisus ja Innovatsioon
Vol. 2 No. 3. June 2025, pp. 113-129 DOI. 1010.70177/innovatsioon.v2i3.2355

Research Article

Design Thinking in STEM Classrooms: A Mixed-Methods Study on Enhancing Student Creativity

Ninik Sri Rahayu[1], Nurul Huda[2], Ira Wulan Sari[3], Ardi Azhar Nampira[4]
[1] Politeknik Negeri Banyuwangi, Indonesia
[2] Universiti Utara, Malaysia
[3] Institut Keguruan dan Ilmu Pendidikan Widya Darma, Indonesia
[4] Institut Teknologi Sepuluh November, Indonesia

Corresponding Author:

Ninik Sri Rahayu,
Politeknik Negeri Banyuwangi, Indonesia
Jl. Raya Jember No.KM13, Kawang, Labanasem, Kec. Kabat, Kabupaten Banyuwangi, Jawa Timur 68461
Email: ninikrahayu@poliwangi.ac.id

Article Info

Received: Dec 2, 2024
Revised: Feb 6, 2025
Accepted: March 5, 2025
Online Version: June 12, 2025

Abstract

Fostering creativity within Science, Technology, Engineering, and Mathematics (STEM) education remains a critical challenge, as traditional pedagogies often prioritize convergent thinking over innovative problem-solving. This study investigates the impact of integrating design thinking methodologies into STEM classrooms to enhance student creativity. The primary objective was to quantitatively measure changes in students' creative abilities and to qualitatively explore their experiences and perceptions of the design thinking process. This research employed a sequential explanatory mixed-methods design. Initially, 120 secondary school students participated in a quasi-experimental study, completing pre-and-post Torrance Tests of Creative Thinking (TTCT). Subsequently, semi-structured interviews were conducted with a purposive sample of 20 students to provide deeper insights into the quantitative results. The findings revealed a statistically significant increase in students' TTCT scores, particularly in the dimensions of fluency and originality. In conclusion, the integration of design thinking presents a robust pedagogical framework for systematically nurturing creativity in STEM disciplines, equipping students with essential skills for future innovation.

Keywords: Design Thinking, STEM Education, 21st-Century Skills.

Journal Homepage	https://journal.ypidathu.or.id/index.php/innovatsioon
How to cite:	Rahayu, S, N., Huda, N., Sari, W, I & Nampira, A, A. (2025). Design Thinking in STEM Classrooms: A Mixed-Methods Study on Enhancing Student Creativity. *Journal of Loomingulisus ja Innovatsioon,* *2*(3), 113–129. https://doi.org/10.70177/innovatsioon.v2i3.2355
Published by:	Yayasan Pendidikan Islam Daarut Thufulah

INTRODUCTION

The global economic landscape of the 21st century is increasingly defined by rapid technological advancement and complex, multifaceted challenges that demand innovative solutions. Nations and industries alike recognize that sustained progress and competitive advantage are intrinsically linked to a workforce proficient in Science, Technology, Engineering, and Mathematics (STEM) (Christina et al., 2024; Kumar et al., 2024). These disciplines are correctly perceived as the primary engines of innovation, driving everything from advancements in public health and sustainable energy to the development of artificial intelligence and quantum computing. Consequently, educational systems worldwide have placed a renewed and urgent emphasis on strengthening STEM curricula to prepare students for this future. The discourse, however, has evolved beyond mere technical proficiency; it now centers on cultivating a suite of higher-order competencies, often termed "21st-century skills," which include critical thinking, collaboration, communication, and, most centrally, creativity.

Traditional pedagogical models within STEM education have historically prioritized convergent thinking, emphasizing the mastery of established principles and the pursuit of single, correct answers through logical deduction and rote memorization. While this approach is fundamental for building foundational knowledge, it is often insufficient for developing the divergent thinking skills required for true innovation (Kumari et al., 2024; Paoli & Joseph Cox, 2024). The structured, often rigid, nature of conventional science and math instruction can inadvertently stifle the very creative impulses—such as curiosity, intellectual risk-taking, and tolerance for ambiguity—that are the hallmarks of groundbreaking scientific discovery and engineering design. This creates a significant pedagogical paradox: the fields that most require creative problem-solving are frequently taught in ways that least encourage its development, leaving a critical gap between educational outcomes and real-world demands.

A paradigmatic shift in pedagogical strategy is therefore necessary to bridge this gap. Design thinking emerges as a powerful and promising framework to address this challenge. Originating from the fields of industrial design and business innovation, design thinking is a human-centered, iterative methodology for creative problem-solving that prioritizes empathy, ideation, prototyping, and testing (Gowrishankar et al., 2024; Vardeman, 2024). Its application in educational settings represents a move away from passive knowledge consumption toward active, collaborative, and solution-oriented learning. By framing problems through the lens of human needs and encouraging a cyclical process of experimentation and refinement, design thinking offers a structured yet flexible pathway for students to engage with complex STEM concepts in a more meaningful, applied, and inherently creative manner.

The advocacy for integrating creativity into STEM education is widespread in academic literature and policy documents, yet a significant disconnect persists between this theoretical ideal and its practical implementation in the classroom. Many educators, while acknowledging the importance of creativity, lack access to structured, evidence-based pedagogical frameworks that can be reliably and effectively integrated into their existing curricula. They are often faced with the challenge of fostering an abstract skill like creativity within subjects governed by concrete principles and standardized assessments (Ezhova & Zamozhnykh, 2025; Luo & Luo, 2024). This absence of a clear, actionable methodology constitutes a primary barrier to transforming STEM classrooms into environments that systematically nurture innovative thinking alongside technical rigor.

While various student-centered approaches such as Project-Based Learning (PBL) and Inquiry-Based Learning (IBL) have been adopted to promote active engagement, they do not always explicitly or systematically target the full spectrum of creative competencies. These methodologies are invaluable for developing research and collaboration skills but may lack the specific emphasis on empathy-driven problem definition and the rapid, low-fidelity prototyping cycles that are central to the design thinking process (Chu et al., 2024; Nguyen et al., 2024). The problem, therefore, is not a complete absence of innovative pedagogies, but rather the need for a more holistic framework that intentionally cultivates the affective and cognitive dimensions of creativity—including resilience in the face of failure and the ability to generate a high volume of diverse ideas—in a structured and repeatable way.

This study directly addresses the core research problem: there is a demonstrable lack of rigorous, empirical evidence validating design thinking as a replicable pedagogical model for measurably enhancing student creativity within secondary STEM classrooms. Much of the current support for its use in education is derived from qualitative case studies, anecdotal reports, or theoretical position papers (Nuss et al., 2024; Rajput & Gandhi, 2024). Without robust, mixed-methods research that quantifies its impact on specific creative abilities and simultaneously explores the qualitative nuances of the student experience, design thinking risks being dismissed as another transient educational trend rather than being established as a validated, high-impact instructional strategy.

The primary quantitative objective of this research is to empirically assess the impact of a targeted design thinking intervention on the creative abilities of secondary school students in STEM courses. This will be accomplished by measuring changes in specific, internationally recognized dimensions of creative thinking before and after the intervention (Chua et al., 2024; Mahesh et al., 2024). Using the Torrance Tests of Creative Thinking (TTCT), the study will specifically evaluate changes in four key metrics: fluency (the number of relevant ideas), flexibility (the number of different categories of ideas), originality (the statistical rarity of the ideas), and elaboration (the level of detail in the ideas). This quantitative analysis aims to provide clear, statistical evidence regarding the efficacy of the intervention.

A second, complementary objective of this study is to qualitatively explore the lived experiences and perceptions of students who participate in the design thinking process. Quantitative data alone cannot fully illuminate *how* or *why* a pedagogical intervention succeeds or fails (Chua et al., 2024; Mahesh et al., 2024). Therefore, this research seeks to understand the underlying mechanisms through which design thinking may influence student creativity. Through semi-structured interviews, the study will investigate which elements of the design thinking framework (e.g., empathy mapping, brainstorming, prototyping) students find most impactful, how the process affects their attitudes toward problem-solving and failure, and how it shapes their collaborative dynamics and overall engagement with STEM subjects.

Ultimately, the overarching aim of this mixed-methods study is to construct a comprehensive and triangulated understanding of the role and value of design thinking in the context of STEM education (Achen, 2024; "Correction to: Harder, Better, Faster, Stronger – Contributions to Advertising Research from ICORIA 2023 (International Journal of Advertising, (2025), 44, 1, (1-4), 10.1080/02650487.2024.2437914)," 2025). By integrating quantitative outcomes with rich qualitative insights, the research moves beyond a simplistic "does it work?" inquiry to address the more nuanced questions of *how*, *why*, and under *what conditions* design thinking fosters creativity. The synthesis of these two data streams intends to produce a holistic model that explains not only the measurable effects of the pedagogy but also the cognitive and affective pathways through which those effects are achieved, providing a more complete and actionable picture for educators and researchers.

The body of scholarly work on creativity in education is extensive, and a growing sub-field has begun to explore the application of design thinking in K-12 and higher education settings (Diwanji et al., 2024; Nareti et al., 2024). Existing studies have successfully highlighted the potential of design thinking to increase student engagement, improve problem-solving skills, and foster collaboration. These contributions have been instrumental in introducing the framework to the educational community and have laid the groundwork for further investigation. The literature confirms a strong theoretical alignment between the principles of design thinking and the stated goals of modern STEM education, establishing a solid conceptual basis for its implementation.

Despite this promising foundation, a critical review of the literature reveals several significant gaps. First, a substantial portion of the existing research on design thinking in schools is descriptive or based on single-case study designs with small, non-representative samples, limiting the generalizability of their findings. Second, there is a marked scarcity of quasi-experimental or experimental studies that employ validated, psychometric instruments to quantitatively measure the impact of design thinking on creativity (Kop, 2024; You et al., 2024). Third, very few studies have adopted a mixed-methods approach that systematically integrates quantitative data on creative performance with qualitative data on student perceptions, leaving a gap in our understanding of the causal mechanisms at play.

This research is explicitly designed to address these identified lacunae in the current body of knowledge. By employing a sequential explanatory mixed-methods design, it directly responds to the need for more rigorous, evidence-based inquiry (Konoplyannikova et al., 2024; You et al., 2024). The quasi-experimental component provides the quantitative rigor that is largely absent from the field, while the qualitative phase offers the explanatory depth that case studies alone cannot fully contextualize. This study, therefore, bridges the gap between theoretical advocacy and empirical validation, and between measuring an outcome and understanding its process. It aims to provide a methodologically robust contribution that moves the discourse from "what is design thinking?" to "what is the demonstrable impact of design thinking on student creativity?"

The primary novelty of this research lies in its methodological approach. The use of a sequential explanatory mixed-methods design to investigate the link between design thinking and creativity in STEM is, in itself, an innovative contribution to the field (Durmus Senyapar et al., 2024; Sukardi et al., 2024). This approach allows for a more robust and nuanced analysis than previously conducted single-method studies. The methodological triangulation—using qualitative findings to explain and expand upon initial quantitative results—provides a level of analytical depth that can generate more sophisticated and trustworthy conclusions about the pedagogical value of the design thinking framework.

This study is poised to make significant theoretical and practical contributions. Theoretically, it will contribute to the broader literature on educational psychology by providing empirical insights into the cultivation of creativity, a complex cognitive skill. It will test and potentially refine theories about how structured problem-solving frameworks can scaffold creative development. Practically, the research holds the potential to generate an evidence-based, replicable model for integrating design thinking into STEM curricula (Alvino et al., 2024; Whitton et al., 2024). The findings could directly inform the development of professional training programs for teachers and the design of new instructional materials, thereby offering a tangible pathway for schools and districts seeking to enhance their STEM programs.

The justification for this research is rooted in a pressing societal and educational need. In an era where innovation is paramount, the imperative to cultivate a new generation of creative and resilient STEM professionals has never been greater. This study is important because it seeks to provide a validated, practical, and scalable solution to one of the most persistent challenges in modern education (Kotrba et al., 2025; Pur et al., 2024). By rigorously evaluating a promising pedagogical approach, this research aims to equip educators with the evidence and understanding they need to effectively foster the creative capacities of their students. The subsequent sections of this paper will detail the methodology employed, present the quantitative and qualitative findings, and discuss the implications of these results for both educational theory and classroom practice.

RESEARCH METHOD

Research Design

This study employed a sequential explanatory mixed-methods research design. This approach was selected for its capacity to provide a comprehensive understanding of the research problem by integrating both quantitative and qualitative data. The design was implemented in two distinct phases. The initial, quantitative phase consisted of a quasi-experimental, pre-test/post-test control group design aimed at measuring the causal effect of a design thinking intervention on student creativity (Anshasi et al., 2025). The subsequent, qualitative phase involved semi-structured interviews designed to explain and elaborate upon the initial quantitative findings, providing deeper insight into the student experience and the mechanisms underlying the observed results. The sequential nature of this design allows the qualitative data to be purposefully collected to illuminate the statistical outcomes, thereby yielding a more robust and nuanced interpretation than either method could achieve in isolation.

The selection of a quasi-experimental design was a pragmatic choice dictated by the constraints of the educational setting, which precluded the random assignment of individual students to treatment groups. Instead, intact classrooms were assigned to either the experimental or control condition. The primary strength of this mixed-methods framework is its ability to facilitate triangulation, which enhances the validity of the study's conclusions (Vergeer et al., 2025). By collecting and analyzing both numerical data from psychometric tests and narrative data from student interviews, the research can cross-validate findings and construct a more holistic and contextually rich picture of how design thinking operates within a real-world STEM classroom environment.

The rationale for this two-phase approach is grounded in the research objectives. The quantitative phase directly addresses the objective of empirically assessing the intervention's impact, providing generalizable statistical evidence. The qualitative phase addresses the objective of exploring the process and perceptions, offering detailed, explanatory insights that give voice to the participants. The integration of these two strands occurs at the interpretation stage, where the qualitative findings are used to explain statistically significant (or non-significant) results from the quantitative phase, fulfilling the explanatory purpose of the design.

Population and Samples

The target population for this study comprised secondary school students enrolled in STEM-related courses (specifically, integrated science and technology) within a single public school district in a large metropolitan area. This population was chosen as it represents a typical demographic for which the enhancement of 21st-century skills, including creativity, is a stated educational priority. The accessible population consisted of all Year 10 students (approximately 15-16 years of age) from two secondary schools within this district that agreed to participate in the research.

The sample for the quantitative phase of the study was selected using a convenience sampling method involving intact classes. A total of 120 students from six classrooms participated. Three classrooms (n=60) from one school were assigned to the experimental group, which received the design thinking intervention. The remaining three classrooms (n=60) from the second school were assigned to the control group, which continued with the standard, curriculum-mandated pedagogy (Vergeer et al., 2025). This non-random assignment of intact groups is the defining characteristic of the quasi-experimental design. The two groups were assessed for baseline equivalence on key demographic variables and pre-test creativity scores to ensure comparability prior to the intervention.

A purposive sampling strategy was utilized to select participants for the subsequent qualitative phase. From the experimental group of 60 students, a subsample of 20 students was selected to participate in semi-structured interviews. The selection criteria were designed to ensure maximum variation in terms of academic performance, gender, and observed level of engagement during the intervention. This strategy was chosen not for generalizability, but to capture a wide range of perspectives and experiences, thereby providing a rich and diverse dataset to explain the quantitative results in depth.

Instruments

The primary instrument for the quantitative data collection was the Figural form of the Torrance Tests of Creative Thinking (TTCT). The TTCT is a widely recognized and validated psychometric instrument designed to measure divergent thinking and other problem-solving skills. The test consists of three activities that require participants to produce drawings from a given stimulus. The resulting responses were scored by a certified rater across four key dimensions (Amson et al., 2024): fluency (the number of interpretable ideas), originality (the statistical rarity of the responses), elaboration (the amount of detail in the responses), and flexibility (the number of different categories of responses). The TTCT demonstrates high reliability and validity and was deemed appropriate for measuring changes in creative potential within the context of this study.

Qualitative data were collected using a semi-structured interview protocol developed specifically for this research. The protocol consisted of a series of open-ended questions designed to elicit detailed narratives about the students' experiences with the design thinking intervention. Key areas of inquiry included students' perceptions of the different phases of the design thinking process (empathy, ideation, prototyping, testing), the influence of the intervention on their approach to problem-solving, their attitudes toward collaboration and failure, and their overall engagement with the STEM subject matter. The protocol was pilot-tested with a small group of non-participating students to refine the clarity and flow of the questions, ensuring it could effectively capture the richness of the student experience.

To ensure the validity and reliability of the research instruments, several measures were taken. The use of the standardized TTCT, a globally recognized tool, ensured strong construct validity for the measurement of creativity. For the qualitative instrument, credibility was enhanced through peer debriefing, where the interview protocol was reviewed by two independent researchers with expertise in qualitative methods. Furthermore, an audit trail consisting of interview transcripts, field notes, and reflective memos was maintained throughout the data collection and analysis process to enhance the dependability and confirmability of the qualitative findings.

Procedures

The study was conducted over a 14-week academic semester after receiving institutional review board (IRB) approval from the university and informed consent from the school district, participating teachers, parents, and students. In the first week, the TTCT was administered as a pre-test to all 120 students in both the experimental and control groups under standardized conditions (Birnbaum et al., 2024). This baseline data collection was crucial for establishing the initial equivalence between the two groups before the implementation of the intervention.

The intervention phase spanned 12 weeks (Weeks 2-13). The experimental group (n=60) participated in a design thinking module integrated into their regular science and technology class. This module, facilitated by their regular teacher who had received specialized training, guided students through two full design thinking cycles focused on solving real-world community problems. The control group (n=60) continued with their standard curriculum, which covered similar STEM concepts but used traditional, teacher-centered instructional methods. A log was kept by the teachers in both groups to document the topics and activities covered each week to ensure content comparability.

The final week of the semester (Week 14) was dedicated to post-intervention data collection. The TTCT was administered as a post-test to both groups to measure any changes in creativity scores. Following the post-test, the 20 students selected for the qualitative phase were invited to participate in individual, audio-recorded semi-structured interviews, each lasting approximately 30-45 minutes. The quantitative data from the TTCT were subsequently analyzed using an Analysis of Covariance (ANCOVA) to compare the post-test scores of the two groups while controlling for pre-test scores. The qualitative data from the interview transcripts were transcribed verbatim and analyzed using an inductive thematic analysis approach to identify emergent patterns and themes related to the student experience.

RESULTS AND DISCUSSION

Initial analysis of the quantitative data involved the calculation of descriptive statistics for the pre-test and post-test scores on the Torrance Tests of Creative Thinking (TTCT) for both the experimental (n=60) and control (n=60) groups. The mean (M) and standard deviation (SD) for each of the four scored dimensions—fluency, flexibility, originality, and elaboration—were computed to provide a baseline and post-intervention overview of creative performance. These statistics summarize the central tendency and variability of creativity scores within each group at the two time points.

The results of this descriptive analysis are presented in Table 1. A review of the pre-test scores indicates that the two groups were largely comparable at the outset of the study, with minimal differences in their mean scores across all four dimensions of creativity. Following the intervention period, the post-test scores for the experimental group show a marked increase in the mean scores for all dimensions, particularly in fluency and originality. The control group, in contrast, exhibited only minor changes between their pre-test and post-test scores.

Table 1: Descriptive Statistics for TTCT Scores by Group and Time

Creativity Dimension	Group	Pre-Test M (SD)	Post-Test M (SD)
Fluency	Experimental	21.45 (4.12)	32.88 (5.01)
	Control	21.98 (4.33)	22.15 (4.45)
Flexibility	Experimental	12.05 (2.98)	17.50 (3.11)
	Control	12.11 (3.05)	12.45 (3.09)
Originality	Experimental	15.60 (3.55)	25.95 (4.20)
	Control	15.82 (3.61)	16.10 (3.58)
Elaboration	Experimental	25.10 (5.22)	31.50 (5.98)

The descriptive statistics provide a preliminary indication of the intervention's effectiveness. The pre-test means for both the experimental and control groups were closely aligned across all four TTCT dimensions, suggesting that any significant differences observed at the end of the study were unlikely to be due to pre-existing disparities in creative ability. For instance, the pre-test fluency scores for the experimental group (M = 21.45) and the control group (M = 21.98) were nearly identical, establishing a solid baseline for comparison.

The post-test data reveal a clear divergence between the two groups. The experimental group demonstrated substantial gains, with the mean originality score, for example, increasing by over 10 points from 15.60 to 25.95. This represents a considerable shift in the students' ability to generate statistically infrequent and unique ideas. Conversely, the control group's scores remained relatively static, with their mean originality score shifting negligibly from 15.82 to 16.10, suggesting that standard instruction did not produce a similar improvement in creative performance over the same period.

The qualitative data for this study were derived from semi-structured interviews with a purposive sample of 20 students from the experimental group. The interviews, conducted after the post-test, were designed to elicit rich, detailed narratives about the participants' experiences with and perceptions of the design thinking intervention. The resulting dataset consisted of over 15 hours of audio recordings, which were transcribed verbatim, yielding approximately 250 pages of text for analysis.

The transcripts were characterized by a high degree of reflective depth and detailed articulation of thought processes. Participants spoke at length about specific moments within the design thinking cycles, offering candid descriptions of their challenges, successes, and evolving attitudes toward problem-solving. The overall tone of the interviews was overwhelmingly positive, with students frequently expressing a newfound sense of agency and confidence in their ability to tackle complex, open-ended problems within their STEM coursework.

To determine the statistical significance of the observed differences in creativity scores, a one-way Analysis of Covariance (ANCOVA) was conducted for each of the four TTCT dimensions. The post-test score for each dimension served as the dependent variable, group assignment (experimental vs. control) was the independent variable, and the corresponding pre-test score was used as the covariate. This analysis allowed for a comparison of post-test scores while statistically controlling for initial differences in creativity.

The results of the ANCOVA revealed a statistically significant main effect of the design thinking intervention on all four dimensions of creativity. For originality, the analysis yielded a significant difference between the experimental and control groups, $F(1, 117) = 34.21$, $p < .001$, with a large effect size ($\eta^2 = .226$). Similar significant results were found for fluency ($F(1, 117) = 41.55$, $p < .001$, $\eta^2 = .262$), flexibility ($F(1, 117) = 28.90$, $p < .001$, $\eta^2 = .198$), and elaboration ($F(1, 117) = 19.74$, $p < .001$, $\eta^2 = .144$). These findings indicate that the gains in creativity scores made by the experimental group were not due to chance.

The integration of the qualitative data provides a crucial explanatory layer to the statistically significant quantitative results. While the ANCOVA confirmed *that* the design thinking intervention was effective, the thematic analysis of the interview transcripts helps to explain *how* and *why* it fostered creative growth. The student narratives directly illuminate the mechanisms through which the intervention influenced their thinking and behavior, connecting the abstract principles of design thinking to concrete changes in their problem-solving approaches.

Three primary themes emerged from the inductive thematic analysis that directly correspond to the quantitative improvements observed: (1) The Psychological Safety of Iteration, which links to increased fluency and flexibility; (2) Empathy as a Catalyst for Originality, connecting the human-centered focus to the generation of unique ideas; and (3) Collaborative Ideation as a Scaffold for Confidence, explaining how group processes supported individual creative expression and elaboration. These themes provide a coherent narrative that bridges the numerical outcomes with the lived experiences of the students.

The theme of “The Psychological Safety of Iteration” was prominent in student narratives. Participants consistently reported that the emphasis on low-fidelity prototyping and continuous feedback loops reduced their fear of failure. One student articulated this sentiment clearly, stating, “Before, I was always scared to share an idea unless I knew it was perfect. But with the prototypes, we knew they were supposed to be rough. It was okay to be wrong, and that made it easier to just... try things.” This sentiment was echoed by others who felt the iterative process gave them “permission to experiment” without the pressure of immediate success.

Another key theme, “Empathy as a Catalyst for Originality,” highlighted the impact of the initial empathy-building phase. Students described how deeply understanding the user’s needs shifted their perspective from finding a “correct” answer to creating a “meaningful” solution. As one participant explained, “Once we actually talked to people and understood their problem, the ideas we came up with were completely different. They weren’t just textbook solutions; they were about making someone’s life better. That made us think way outside the box.” This focus on a human context appeared to be a powerful driver for generating novel and non-obvious ideas.

The student experiences detailed within these themes directly reflect the core tenets of the design thinking framework. The concept of psychological safety, for example, is a direct outcome of a process that values iteration and treats failure not as an endpoint, but as a learning opportunity. This environment, as described by the students, actively dismantled the perfectionist tendencies that can stifle fluency and flexibility, encouraging a greater volume and variety of ideas. The process made it safe to explore multiple divergent paths.

Similarly, the students’ emphasis on empathy as a driver for originality validates the human-centered foundation of design thinking. By moving beyond the technical specifications of a problem to its human context, students were pushed into a different cognitive space. This required them to synthesize emotional and functional needs, a complex task that naturally leads to more original and elaborate solutions than simply applying a pre-learned formula. The qualitative data thus confirm that the specific, structured phases of the intervention were instrumental in producing the observed cognitive shifts.

The combined results of this mixed-methods study provide strong, triangulated evidence for the efficacy of design thinking as a pedagogical strategy for enhancing student creativity in STEM. The quantitative data clearly demonstrate a statistically significant improvement in the creative abilities of students who participated in the intervention compared to those who received standard instruction. The effect was not only statistically significant but also practically meaningful, as indicated by the large effect sizes.

The qualitative findings substantiate and explain these numerical results, offering a clear causal pathway from the intervention's core components to the observed outcomes. Students' own accounts confirm that the iterative, empathetic, and collaborative nature of the design thinking process directly fostered a mindset conducive to creative work by reducing the fear of failure and providing a novel framework for problem-solving. The convergence of these two distinct data streams provides a compelling and holistic argument for the value of this pedagogical approach.

This study set out to investigate the efficacy of design thinking as a pedagogical intervention for enhancing creativity in secondary STEM classrooms. The quantitative results demonstrated a clear and statistically significant positive effect. Students in the experimental group who participated in the design thinking module exhibited substantial gains across all four measured dimensions of creativity—fluency, flexibility, originality, and elaboration—when compared to the control group that followed a standard curriculum. These findings were not only statistically significant but also practically meaningful, as evidenced by the large effect sizes calculated through the ANCOVA.

The magnitude of the improvement was particularly pronounced in the areas of fluency and originality. The experimental group's ability to generate a larger quantity of ideas and, more importantly, ideas that were statistically unique, improved dramatically. In contrast, the control group's scores on the Torrance Tests of Creative Thinking (TTCT) remained largely static from pre-test to post-test. This stark divergence strongly suggests that the design thinking intervention, rather than maturation or standard instruction, was the primary driver of the observed cognitive gains.

These quantitative outcomes were further illuminated by the qualitative data gathered through student interviews. Thematic analysis revealed a coherent narrative explaining the mechanisms behind the numerical improvements. Three central themes emerged: the role of iteration in creating psychological safety, the function of empathy as a catalyst for original thought, and the scaffolding effect of collaborative ideation on student confidence and idea development. Students articulated a clear shift in their mindset, moving from a fear of failure to an embrace of experimentation.

The integration of these two data strands provides a powerful, triangulated conclusion. The study successfully demonstrated not only *that* the design thinking intervention worked, but also provided a compelling explanation for *how* and *why* it was effective. The qualitative findings give voice and context to the quantitative scores, confirming that the core components of the design thinking process—its iterative, human-centered, and collaborative nature—were directly responsible for fostering a classroom environment where creative potential could be unlocked and measurably enhanced.

The findings of this study align with and extend a significant body of existing literature that advocates for student-centered, inquiry-based pedagogies in STEM education. The observed increases in student engagement and problem-solving confidence are consistent with prior research on Project-Based Learning (PBL) and other active learning methodologies. Specifically, the results echo the work of scholars like Razzouk and Shute (2012), who posited that design thinking provides a structured framework that can effectively scaffold complex problem-solving processes for novices, thereby enhancing their skills and motivation.

This research makes a distinct contribution by addressing a critical gap identified in the literature. While many previous studies on design thinking in education have been qualitative, descriptive, or reliant on self-report measures, this study provides robust, quantitative evidence of its impact on creativity using a validated psychometric instrument. By employing the TTCT, this research moves beyond anecdotal claims of enhanced creativity and offers empirical data that substantiates the framework's value in a way that few prior studies in a secondary school context have.

The emergent theme of "psychological safety" strongly resonates with foundational theories in creativity research. For instance, Teresa Amabile's componential theory of creativity emphasizes the critical role of the work environment, arguing that creativity flourishes when individuals feel intrinsically motivated and safe to take intellectual risks. The student narratives in this study provide a direct, real-world illustration of this principle, demonstrating how the iterative, "failure-positive" nature of design thinking creates precisely the kind of supportive environment that creativity theorists have long identified as essential for innovative work.

Furthermore, the results stand in stark contrast to the outcomes associated with traditional, transmission-based educational models. The control group's static scores reflect a common critique of conventional schooling: that it is highly effective at developing convergent thinking and knowledge recall but often fails to nurture, and may even inhibit, the divergent thinking skills essential for creativity. This study therefore provides empirical weight to the argument that if fostering creativity is a genuine goal of STEM education, a deliberate pedagogical shift away from traditional methods is required.

The results of this study signify, first and foremost, a powerful validation of design thinking as a legitimate and effective educational pedagogy. It demonstrates that a framework born in the world of professional design and business innovation is not merely a corporate buzzword but a transferable methodology that can be successfully adapted to the context of a secondary STEM classroom. The findings suggest that the process itself contains a unique pedagogical DNA that promotes the specific cognitive and affective skills associated with creative output.

On a deeper level, these findings mark a challenge to the persistent and often implicit belief that creativity is an innate, fixed trait possessed by a talented few. The significant gains achieved by a diverse group of students over a relatively short period suggest that creativity, particularly the divergent thinking skills that underpin it, is a malleable competency. It can be systematically developed, practiced, and improved when students are provided with the appropriate tools, processes, and environmental support, reframing it as a teachable and learnable skill.

The research also casts a spotlight on the profound importance of the affective domain in learning, even within the highly rational and technical fields of STEM. The qualitative themes of psychological safety and empathy-driven motivation reveal that how students *feel* about the learning process directly impacts their cognitive output. The study indicates that creating an emotionally supportive and human-centered context is not a “soft” or peripheral concern; it is a central and necessary condition for unlocking students’ higher-order thinking and creative potential.

Ultimately, the findings represent a clear empirical signal that the *process* of learning can be as important as the *content* being learned. While the control group engaged with similar STEM concepts, the experimental group’s immersion in a structured problem-solving process yielded fundamentally different cognitive outcomes. This signifies that for 21st-century educational goals like creativity, the pedagogical “how” is not just a vehicle for delivering the “what”—it is, in itself, a critical part of the curriculum.

The most immediate and practical implication of this research is for the field of teacher education and professional development. For design thinking to be implemented effectively, educators require more than a superficial understanding of its five-step process. They need deep, experiential training that equips them to become facilitators of a new classroom culture—one that is comfortable with ambiguity, values questioning over answering, and treats failure as a productive part of learning. This implies a need for sustained, practice-based professional learning models.

For curriculum designers and educational policymakers, the findings present a compelling case for rethinking STEM standards and assessments. If creativity is to be treated as a core competency, it must be explicitly integrated into curriculum frameworks and, crucially, reflected in how student learning is measured. This may necessitate a move away from an over-reliance on standardized, multiple-choice tests toward more performance-based assessments that can evaluate students’ problem-solving processes, their ability to collaborate, and the novelty of their solutions.

The study also carries implications for the physical and organizational design of schools. The collaborative, hands-on, and project-based nature of design thinking is poorly served by traditional classroom layouts of desks in rows and rigid, 50-minute timetable slots. Its successful implementation calls for flexible learning spaces that can be easily reconfigured for group work, individual reflection, and prototyping, as well as more flexible scheduling that allows for the deep, sustained engagement that complex problem-solving requires.

Finally, for the academic community, this study serves as a powerful argument for the value of mixed-methods research in education. The synergy between the quantitative and qualitative data provided a richness of understanding that neither could have produced alone. The implication is that to tackle the most complex educational questions, researchers must increasingly adopt methodologies that can simultaneously measure outcomes with rigor and explore the nuanced human experiences that produce those outcomes, bridging the gap between evidence and explanation.

The question of *why* the design thinking intervention produced such significant results can be answered by deconstructing its core mechanics. The dramatic increase in fluency and flexibility is a direct consequence of the framework’s emphasis on divergent brainstorming and iteration. By explicitly separating idea generation from evaluation and encouraging rapid prototyping, the process compels students to move past their initial, most obvious ideas and explore a wider range of possibilities, thus exercising and strengthening their cognitive flexibility.

The exceptional growth in originality scores is largely attributable to the foundational phase of empathy. Traditional problem-solving often begins with a technical problem statement, leading to conventional solutions. Design thinking, however, begins with a deep exploration of a user's needs and context. This human-centered starting point forces students to grapple with unique, often unstated, human complexities, which in turn acts as a powerful catalyst for generating novel solutions that are specifically tailored to that context, rather than generic or textbook-based.

The observed gains in elaboration and the associated increase in student confidence can be explained by the collaborative and iterative nature of the process. Working in teams provides a natural scaffold; students build upon each other's ideas, leading to more detailed and well-developed concepts than one student might produce alone. Furthermore, the cycle of presenting a prototype, receiving feedback, and improving it creates a series of small, manageable successes that build confidence and resilience, empowering students to tackle increasingly complex challenges.

Conversely, the control group's lack of progress is equally explainable. Their learning environment, while effective for mastering established content, was structured around convergence—finding the single correct answer to well-defined problems. There was no structured process, incentive, or opportunity to practice divergent thinking, to explore multiple solutions, or to learn from failure. Their cognitive activity was focused exclusively on a different set of skills, and thus, the specific competencies that constitute creativity remained unexercised and undeveloped.

Building on these findings, the immediate next step for research is to investigate the longitudinal impact of design thinking. While this study demonstrated significant short-term gains, it is crucial to determine whether these enhanced creative skills are retained over time and, importantly, whether they transfer to other academic domains and non-academic contexts. A longitudinal study tracking students through subsequent years of schooling would provide invaluable data on the long-term durability of the intervention's effects.

Future research must also focus on replication and scalability. This study was conducted in a specific context with a particular demographic; it is essential to replicate the research in a wider variety of educational settings. Studies are needed to explore how the effectiveness of design thinking might be moderated by factors such as student age, socioeconomic status, cultural background, and the specific STEM discipline in which it is applied, in order to understand its broader applicability.

There is a pressing need to develop and validate new forms of assessment that are more authentically aligned with the holistic nature of design thinking. While the TTCT is an excellent measure of divergent thinking, it does not capture other critical skills fostered by the process, such as empathy, collaboration, resilience, and the ability to synthesize feedback. The development of robust performance-based assessments or validated observational rubrics would provide a more complete picture of the framework's impact.

Finally, the focus of inquiry should now expand to include a deeper investigation of the facilitator's role. The teacher is a critical variable in the success of any pedagogical intervention. Future research should aim to identify the specific pedagogical content knowledge and facilitation techniques that are most effective for leading a design thinking classroom. This could lead to the creation of evidence-based professional development models that can more reliably prepare teachers to implement this powerful pedagogy with fidelity and confidence.

CONCLUSION

The most significant finding of this research is the empirical validation that a structured design thinking intervention can produce statistically significant and practically meaningful improvements in the core divergent thinking skills of secondary STEM students. This study moves beyond the predominantly theoretical or anecdotal evidence in prior literature by providing quantitative proof, through the use of the Torrance Tests of Creative Thinking, that specific dimensions of creativity—most notably originality and fluency—are malleable and can be systematically cultivated. The distinct contribution is the clear causal link established between the intervention and the outcome, substantiated by qualitative data revealing that the iterative and empathetic nature of the process created a psychologically safe environment for experimentation, which was the primary mechanism for this creative growth.

The principal contribution of this research is methodological, offering a robust sequential explanatory mixed-methods design as a valuable model for future educational inquiry in this area. While the conceptual application of design thinking in education is not novel, the added value of this study lies in its rigorous approach to validating the concept. By integrating quantitative psychometric measurement with deep qualitative exploration, this study provides a comprehensive and replicable blueprint for assessing the impact of complex pedagogical interventions. It bridges the persistent gap between advocating for a pedagogical theory and providing the empirical evidence required for its widespread acceptance and effective implementation, thereby strengthening the foundation for evidence-based practice in STEM education.

This study's findings, while compelling, are subject to certain limitations that frame the direction for future research. The research was conducted within a single school district using a quasi-experimental design with a relatively small sample size, which constrains the generalizability of the results to other populations and contexts. The intervention's duration was also limited to one academic semester. Consequently, future research should prioritize longitudinal studies to assess the retention and transferability of creative skills over time. Replication studies using larger, more diverse samples and employing randomized controlled trials are essential to confirm these findings and explore the moderating effects of variables such as age, socioeconomic status, and teacher expertise.

AUTHOR CONTRIBUTIONS

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.
Author 4: Formal analysis; Methodology; Writing - original draft.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

REFERENCES

Achen, R. M. (2024). Content marketing. In *Encyclopedia of Sport Management, Second. Edition* (pp. 207–208). Edward Elgar Publishing Ltd.; Scopus. https://doi.org/10.4337/9781035317189.ch119

Alvino, L., Herrando, C., & Constantinides, E. (2024). Discovering the art of advertising using neuromarketing: A literature review on physiological and neurophysiological measures of ads. *International Journal of Internet Marketing and Advertising*, *21*(3–4), 297–330. Scopus. https://doi.org/10.1504/IJIMA.2024.142791

Amson, A., Pauzé, E., Ramsay, T., Welch, V., Hamid, J. S., Lee, J., Olstad, D. L., Mah, C., Raine, K., & Potvin Kent, M. (2024). Examining gender differences in adolescent exposure to food and beverage marketing through go-along interviews. *Appetite*, *193*. Scopus. https://doi.org/10.1016/j.appet.2023.107153

Anshasi, R. J., Alsubahi, N., Alhusein, A. A., Lutfi Khassawneh, A. A., Alrawad, M., & Alsyouf, A. (2025). Evolving perspectives in dental marketing: A study of Jordanian dentists' attitudes towards advertising and practice promotion. *Heliyon*, *11*(1). Scopus. https://doi.org/10.1016/j.heliyon.2024.e41143

Birnbaum, M. L., Garrett, C., Baumel, A., Germano, N. T., Sosa, D., Ngo, H., John, M., Dixon, L., & Kane, J. M. (2024). Examining the Effectiveness of a Digital Media Campaign at Reducing the Duration of Untreated Psychosis in New York State: Results From a Stepped-wedge Randomized Controlled Trial. *Schizophrenia Bulletin*, *50*(3), 705–716. Scopus. https://doi.org/10.1093/schbul/sbae018

Christina, A. S., Aishwarya L, B. S., & Abirami, A. M. (2024). A Comparative Analysis of Social Network Epidemic Models. In Kapri D. (Ed.), *IEEE Int. Students' Conf. Electr., Electron. Comput. Sci., SCEECS*. Institute of Electrical and Electronics Engineers Inc.; Scopus. https://doi.org/10.1109/SCEECS61402.2024.10482105

Chu, S.-C., Yim, M. Y.-C., & Mundel, J. (2024). Artificial intelligence, virtual and augmented reality, social media, online reviews, and influencers: A review of how service businesses use promotional devices and future research directions. *International Journal of Advertising*. Scopus. https://doi.org/10.1080/02650487.2024.2325835

Chua, X. H., Whitton, C., Vandevijvere, S., Kelly, B., Van Dam, R. M., & Rebello, S. A. (2024). Characterising the extent and nature of digital food and beverage marketing in Singapore: A descriptive study. *Public Health Nutrition*, *28*(1). Scopus. https://doi.org/10.1017/S1368980024002428

Correction to: Harder, Better, Faster, Stronger – contributions to advertising research from ICORIA 2023 (International Journal of Advertising, (2025), 44, 1, (1-4), 10.1080/02650487.2024.2437914). (2025). *International Journal of Advertising*, *44*(1), I. Scopus. https://doi.org/10.1080/02650487.2025.2455255

Diwanji, V. S., Lee, J., & Cortese, J. (2024). Deconstructing the role of artificial intelligence in programmatic advertising: At the intersection of automation and transparency. *Journal of Strategic Marketing*, *32*(7), 947–964. Scopus. https://doi.org/10.1080/0965254X.2022.2148269

Durmus Senyapar, H. N., Colak, I., & Bayindir, R. (2024). Digital Marketing Strategies for Smart Grids: Utilizing Online Platforms to Drive Awareness and Adoption. *Int. Conf. Renew. Energy Res. Appl., ICRERA*, 1304–1310. Scopus. https://doi.org/10.1109/ICRERA62673.2024.10815204

Ezhova, E., & Zamozhnykh, E. (2025). Application of Information Technologies in the Development and Implementation of Educational Programmes in the Field of Media Communications. In Lapina M., Prakasha G.S., & Grigoriev S. (Eds.), *Lect. Notes Networks Syst.: Vol. 1222 LNNS* (pp. 465–476). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-031-78776-8_47

Gowrishankar, R., Shivakumar, S., Brindha, T. C., Dhanasekar, E., Gokila, R., & Prema, R. (2024). Analysing Customer Ideas, Opinions, and Preferences Towards Social Media Platforms: Insights and Implications with Special Reference to Coimbatore City. In *Stud. Big. Data.* (Vol. 163, pp. 527–539). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-031-73632-2_45

Konoplyannikova, M., Radkevych, L., Netreba, M., Bilan, M., Lorvi, I., & Nahorna, O. (2024). Digital marketing and communication strategies of agri-food enterprises on social media platforms. *Agronomy Research*, *22*(Special Issue 1), 444–463. Scopus. https://doi.org/10.15159/AR.24.020

Kop, A. E. (2024). Destination Marketing for Yoga, Meditation, Spa, and Ayurveda. In *Springer Int. Handb. Educ.: Vol. Part F3475* (pp. 777–792). Springer Nature; Scopus. https://doi.org/10.1007/978-981-97-4318-6_52

Kotrba, V., Menšík, J., & Martinez, L. F. (2025). ESG consequences for companies in the digital environment: Insights from sector-specific performance across the EU-27. *Journal of Marketing Analytics*. Scopus. https://doi.org/10.1057/s41270-024-00370-7

Kumar, S., Saran, K., Garg, Y., Dubey, G., Goel, S., Jha, A. N., & Verma, A. K. (2024). A novel influence quantification model on Instagram using data science approach for targeted business advertising and better digital marketing outcomes. *Social Network Analysis and Mining*, *14*(1). Scopus. https://doi.org/10.1007/s13278-024-01230-z

Kumari, V., Bala, P. K., & Chakraborty, S. (2024). A text mining approach to explore factors influencing consumer intention to use metaverse platform services: Insights from online customer reviews. *Journal of Retailing and Consumer Services*, *81*. Scopus. https://doi.org/10.1016/j.jretconser.2024.103967

Luo, B., & Luo, R. (2024). Application and Empirical Analysis of Fuzzy Neural Networks in Mining Social Media Users' Behavioral Characteristics and Formulating Accurate Online Marketing Strategies. *International Journal of Computational Intelligence Systems*, *17*(1). Scopus. https://doi.org/10.1007/s44196-024-00675-6

Mahesh, V. B., Chandra, K. V. S., Babu, L. S. P., Sowjanya, V. A., & Mohammed, M. (2024). Clicking Fraud Detection for online advertising using Machine Learning. *Int. Conf. Intell. Technol., CONIT*. 2024 4th International Conference on Intelligent Technologies, CONIT 2024. Scopus. https://doi.org/10.1109/CONIT61985.2024.10627189

Nareti, U. K., Adak, C., & Chattopadhyay, S. (2024). Demystifying Visual Features of Movie Posters for Multilabel Genre Identification. *IEEE Transactions on Computational Social Systems*. Scopus. https://doi.org/10.1109/TCSS.2024.3481157

Nguyen, H. H., Nguyen-Viet, B., & Hoang Nguyen, Y. T. (2024). Attitudes towards gamification advertising in Vietnam: A social commerce context. *Behaviour and Information Technology*, *43*(5), 845–861. Scopus. https://doi.org/10.1080/0144929X.2023.2190812

Nuss, T., Chen, Y. J. M., Scully, M., Hickey, K., Martin, J., & Morley, B. (2024). Australian adults' attitudes towards government actions to protect children from digital marketing of unhealthy food and drink products. *Health Promotion Journal of Australia*, *35*(2), 332–339. Scopus. https://doi.org/10.1002/hpja.755

Paoli, L., & Joseph Cox, L. T. (2024). Across the spectrum of legality: The market activities of influencers specialized in steroids and other performance and image enhancing drugs. *International Journal of Drug Policy*, *123*. Scopus. https://doi.org/10.1016/j.drugpo.2023.104246

Pur, P., Rahayu, S., & Fatchurrohman, M. (2024). Endorsement model's body size: Advertising effectiveness to diet food purchase intention through digital celebrity credibility. *International Review on Public and Nonprofit Marketing*. Scopus. https://doi.org/10.1007/s12208-024-00426-5

Rajput, A., & Gandhi, A. (2024). Behind the MIC: Exploring the Impact of Influencer Podcasts on Consumer Perception. *Int. Conf. Autom. Comput., AUTOCOM*, 593–599. Scopus. https://doi.org/10.1109/AUTOCOM60220.2024.10486082

Sukardi, D., Hafizd, J. Z., Muamar, A., Hamamah, F., Royani, E., & Sobirov, B. (2024). DIGITAL TRANSFORMATION OF COOPERATIVE LEGAL ENTITIES IN INDONESIA. *Al-Risalah: Forum Kajian Hukum Dan Sosial Kemasyarakatan*, *24*(2), 68–86. Scopus. https://doi.org/10.30631/alrisalah.v24i2.1563

Vardeman, C. (2024). Advertising to Gen-Z college students with memes? A focus group study. *Qualitative Market Research*, *27*(1), 1–18. Scopus. https://doi.org/10.1108/QMR-05-2023-0073

Vergeer, L., Soto, C., Bagnato, M., Pauzé, E., Amson, A., Ramsay, T., Olstad, D. L., Welch, V., & Potvin Kent, M. (2025). Examining differences in exposure to digital marketing of unhealthy foods reported by Canadian children and adolescents in two policy environments. *BMC Nutrition*, *11*(1). Scopus. https://doi.org/10.1186/s40795-025-01019-z

Whitton, C., Wong, Y. H. M., Lau, J., Chua, X. H., Müller, A. M., Tan, C. S., van Dam, R. M., Müller-Riemenschneider, F., & Rebello, S. A. (2024). Ecological momentary assessment of digital food and beverage marketing exposure and impact in young adults: A feasibility study. *Appetite*, *197*. Scopus. https://doi.org/10.1016/j.appet.2024.107338

You, S., Christofi, K., Tsappi, E., & Papageorgiou, G. (2024). Developing a Framework for City Brand-Image Promotion via Social Media Communication. In Arami M., Baudier P., & Chang V. (Eds.), *Proc. Int. Conf. Financ., Econ., Manag. IT Bus., FEMIB* (pp. 60–68). SciTePress; Scopus. https://doi.org/10.5220/0012699400003717