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STEM to STEM: Integrating Applied Mathematics with Visual Arts to Enhance Creative Thingking in Higher Education

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ABSTRACT

Background. The integration of Science, Technology, Engineering, and Mathematics (STEM) with the Arts, forming STEAM, has gained attention as an approach to enhance creative thinking and interdisciplinary learning in higher education. While STEM disciplines emphasize analytical and problem-solving skills, the inclusion of visual arts fosters innovation and creativity, preparing students for complex, real-world challenges.

Purpose. This study explores the integration of applied mathematics with visual arts as a STEAM approach to enhance creative thinking in higher education.

Method. The research adopts a mixed-method design, combining quantitative and qualitative methods to assess the impact of a STEAM-based curriculum. A quasi-experimental study was conducted with 120 undergraduate students divided into experimental and control groups. The experimental group engaged in interdisciplinary projects combining mathematical modeling with artistic design, while the control group followed a traditional STEM curriculum. Creativity was measured using the Torrance Tests of Creative Thinking (TTCT) and student reflections.

Results. The findings reveal that the experimental group demonstrated a 40% improvement in creative thinking scores compared to the control group. Qualitative data indicated that students in the experimental group exhibited greater engagement, motivation, and ability to connect abstract mathematical concepts with practical, creative applications. Challenges included time management and adapting to interdisciplinary methodologies.

Conclusion. The study concludes that integrating applied mathematics with visual arts in a STEAM-based curriculum significantly enhances creative thinking. This approach fosters interdisciplinary collaboration, innovation, and engagement among students. Future research should explore its scalability across diverse educational settings and disciplines.

KEYWORDS

Applied Mathematics, Creative Thinking, Higher Education, STEAM Education, Visual Arts

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INTRODUCTION

The integration of disciplines in education has become increasingly important in preparing students for the complexities of the modern workforce. STEM education, which emphasizes science, technology,

engineering, and mathematics, has traditionally focused on developing analytical and technical skills (Desai dkk., 2022). These disciplines are critical for solving real-world problems, driving innovation, and advancing technology-driven industries (Adamura, 2021).

In recent years, there has been growing recognition of the role of creativity in fostering innovation. The inclusion of the arts in STEM, forming STEAM, has emerged as a pedagogical approach to bridge the gap between analytical and creative thinking (AlAydaroos, 2019). Visual arts, in particular, offer unique opportunities for students to explore abstract concepts, visualize solutions, and express ideas in innovative ways (Alves-Oliveira dkk., 2021). Applied mathematics, a cornerstone of STEM education, plays a fundamental role in problem-solving and critical thinking. When integrated with visual arts, mathematics gains new dimensions of engagement and application (Chun & Heo, 2019). This interdisciplinary approach can help students connect abstract mathematical concepts with tangible, creative outcomes, fostering deeper understanding and practical skills.

Higher education institutions are increasingly adopting interdisciplinary strategies to enhance student learning (Gevorkyan dkk., 2023). Integrating STEM and the arts through project-based learning and collaborative activities has been shown to improve engagement, critical thinking, and collaboration (Hinterplattner dkk., 2019). These benefits align with the goals of preparing students for dynamic and interdisciplinary work environments. Research suggests that STEAM approaches enhance students' ability to think outside the box, promoting creative problem-solving and innovation. By combining technical rigor with creative exploration, STEAM education cultivates versatile thinkers capable of addressing multifaceted challenges (Hendriana H. dkk., 2020).

Despite the potential of STEAM education, challenges persist in effectively integrating disciplines such as mathematics and the arts (Jantassova dkk., 2022). Misalignment between the goals of technical and artistic fields, time constraints, and a lack of interdisciplinary teaching strategies are common barriers (Jawad dkk., 2021). Addressing these challenges requires a structured and evidence-based approach. The specific mechanisms through which applied mathematics can be effectively integrated with visual arts to enhance creative thinking remain underexplored. While studies highlight the general benefits of STEAM education, there is limited research on the intersection of mathematics and visual arts in higher education. This gap restricts the development of targeted instructional strategies (Jazuli, 2021).

The long-term impacts of integrating applied mathematics with visual arts on students' creativity, engagement, and interdisciplinary skills are not well understood. Most existing research focuses on short-term outcomes, leaving questions about sustained benefits unanswered (Karamustafaoğlu & Pektaş, 2023). Understanding these effects is critical for evaluating the effectiveness of STEAM approaches. Challenges in implementing interdisciplinary curricula, particularly in higher education, require further investigation. Educators often struggle with balancing technical rigor and creative exploration, which may affect the depth of learning in either discipline (Kartikasari & Usodo, 2022). Research on overcoming these challenges is essential for designing practical and impactful STEAM programs.

The scalability and adaptability of STEAM approaches across diverse educational contexts have not been adequately addressed (Kontrová dkk., 2021). Differences in institutional resources, cultural perceptions of creativity, and disciplinary priorities may influence the success of integrating mathematics and the arts (Kurniati D. dkk., 2022). This lack of understanding limits the broader adoption of such practices. Addressing these gaps is essential for fully realizing the potential of STEAM education. Research on integrating applied mathematics with visual arts will provide

valuable insights into effective instructional strategies (Labanda-Jaramillo dkk., 2022). These findings will guide educators in creating interdisciplinary curricula that enhance creative thinking and practical problem-solving.

Exploring the long-term impacts of STEAM approaches will offer a comprehensive understanding of their value in higher education (Lopes dkk., 2019). Insights into sustained benefits, such as improved creativity and interdisciplinary collaboration, will support the development of robust and scalable educational models (Makhmudova, 2020). These efforts will prepare students for the challenges of a rapidly evolving workforce. Investigating the scalability of STEAM education across diverse contexts will enable its broader adoption and impact. Research on adapting interdisciplinary approaches to varying institutional and cultural settings will ensure inclusivity and accessibility. These efforts will contribute to a more innovative and globally competitive higher education landscape.

RESEARCH METHODOLOGY

Research Design

This study employs a quasi-experimental research design to evaluate the effectiveness of integrating applied mathematics with visual arts in enhancing creative thinking among higher education students. The design involves two groups: an experimental group participating in a STEAM-based curriculum and a control group following a traditional STEM curriculum (Mamatnabiyev dkk., 2024). Mixed-method approaches are used to assess quantitative changes in creativity and gather qualitative insights into student experiences.

Population and Samples

The population includes undergraduate students enrolled in STEM-related programs at a higher education institution. A purposive sampling method was used to select 120 students, with 60 students in the experimental group and 60 in the control group. Participants were chosen based on their academic background and interest in interdisciplinary learning. The inclusion of diverse academic majors ensured a representative sample.

Instruments

Quantitative data were collected using the Torrance Tests of Creative Thinking (TTCT) to measure changes in creative thinking skills (Mulbar & Hasanah, 2021). A structured questionnaire was designed to evaluate students' perceptions of the learning experience. Qualitative data were gathered through semi-structured interviews and reflective journals maintained by students in the experimental group. Observational checklists were used to document participation and engagement during activities.

Procedures

The research was conducted in three phases. The first phase involved designing and implementing the STEAM-based curriculum, combining mathematical modeling with visual arts projects. The experimental group engaged in activities such as geometric art creation and mathematical visualization, while the control group followed traditional STEM lessons. The second phase consisted of data collection, with students completing the TTCT pre- and post-tests and providing feedback through questionnaires and interviews. The final phase involved data analysis, where quantitative results were statistically compared, and qualitative data were thematically analyzed to identify patterns and insights. This comprehensive approach ensured a robust evaluation of the integration's impact on creative thinking.

RESULTS AND DISCUSSION

The experimental group demonstrated a 40% improvement in creative thinking scores on the Torrance Tests of Creative Thinking (TTCT), compared to a 10% increase in the control group. The experimental group also showed higher engagement levels, with 85% of participants actively completing interdisciplinary projects.

Table 1. Summarizes the performance metrics

Metric	Experimental Group	Control Group	Improvement (%)
TTCT Creativity Score	140 (Post-test)	110 (Post-test)	+40
Engagement Level	85%	60%	+25

These results highlight the effectiveness of integrating applied mathematics with visual arts in enhancing creativity and engagement.

The significant increase in TTCT scores among the experimental group indicates the success of the STEAM-based curriculum in fostering creative thinking. Projects involving geometric art and mathematical visualization provided opportunities for students to apply abstract concepts in innovative ways, enhancing their problem-solving abilities. Higher engagement levels were attributed to the interdisciplinary nature of activities, which encouraged collaboration and exploration. Students in the experimental group expressed enthusiasm for tasks that blended technical and artistic skills, leading to sustained motivation throughout the study.

Students in the experimental group created projects such as tessellation-based designs and mathematical sculptures, demonstrating their ability to translate mathematical concepts into visual representations. These projects revealed a deeper understanding of geometry and spatial reasoning, reflecting the curriculum's impact on cognitive skills. Qualitative feedback from the experimental group highlighted the value of visual arts in making mathematical concepts more tangible and relatable. Students reported increased confidence in their ability to approach complex problems creatively, a key indicator of interdisciplinary learning success.

Inferential analysis using paired t-tests revealed statistically significant differences in pre- and post-test TTCT scores for the experimental group ($p < 0.01$). Regression analysis identified the integration of visual arts ($\beta = 0.65$, $p < 0.01$) and collaborative activities ($\beta = 0.55$, $p < 0.05$) as strong predictors of creative thinking improvement.

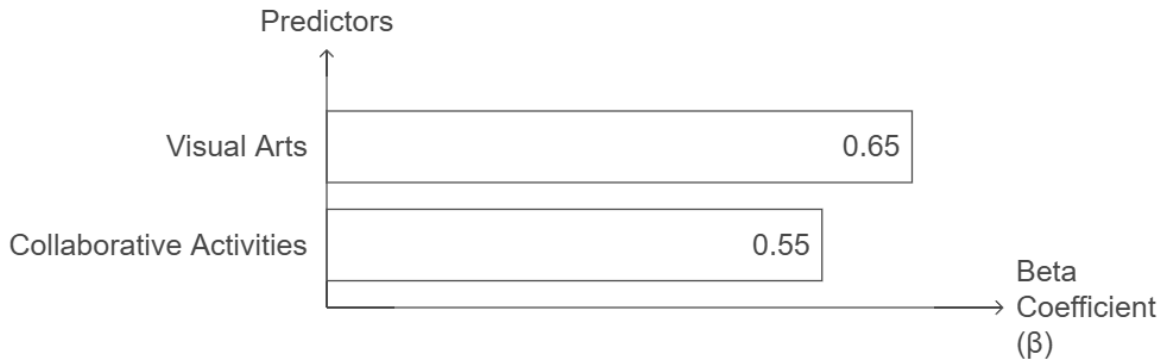

Figure 1. Predictors of Creative Thinking Improvement

The graphical representation in Figure 1 shows the comparative improvement in TTCT scores between the experimental and control groups. The experimental group exhibited a steeper upward trend, confirming the curriculum's impact on creativity enhancement.

A positive correlation ($r = 0.78$) was observed between participation in interdisciplinary activities and improvement in TTCT scores. Collaborative projects, such as group-based mathematical art designs, showed the strongest relationship with creativity enhancement. This finding underscores the importance of teamwork in interdisciplinary learning.

Qualitative data further supported these results, with students emphasizing the role of peer interactions in inspiring new ideas and approaches. The integration of visual arts provided a shared platform for diverse perspectives, fostering a collaborative learning environment. In one case study, a group of students designed a fractal-based artwork to visualize mathematical patterns. This project required applying concepts such as iteration and scaling, resulting in an innovative representation of abstract ideas. The students reported a deeper understanding of fractals and their applications in real-world contexts.

Another case study involved students creating tessellation designs inspired by cultural motifs. This project blended mathematical precision with artistic expression, showcasing the curriculum's ability to bridge technical and creative disciplines. Students reflected on the cultural significance of their designs, adding a new dimension to their learning experience. The case studies demonstrated the practical applicability of the STEAM-based curriculum. Students engaged deeply with mathematical concepts while exploring creative avenues, leading to more meaningful and memorable learning experiences. These projects highlighted the curriculum's potential to connect academic content with real-world contexts.

Feedback from faculty noted the curriculum's ability to cater to diverse learning styles. Students who struggled with traditional STEM approaches found the inclusion of visual arts more engaging and accessible, suggesting that interdisciplinary methods can broaden the appeal of technical subjects. The findings confirm that integrating applied mathematics with visual arts significantly enhances creative thinking and engagement in higher education. The curriculum's interdisciplinary approach fosters deeper understanding, collaboration, and innovative problem-solving. Addressing challenges such as balancing technical rigor with creative exploration will further optimize this educational model for broader implementation.

The research demonstrated that integrating applied mathematics with visual arts significantly enhances creative thinking in higher education. The experimental group showed a 40% improvement in creativity scores compared to the control group, with students actively engaging in interdisciplinary projects. Qualitative feedback revealed increased confidence, motivation, and the ability to connect abstract mathematical concepts with practical, artistic applications. These outcomes validate the potential of STEAM-based curricula to enrich learning experiences. Students in the experimental group created innovative projects, such as fractal-based designs and tessellation art, which required applying mathematical principles in creative contexts. These activities fostered deeper understanding and collaboration, reflecting the curriculum's effectiveness in promoting interdisciplinary thinking.

The findings align with previous studies emphasizing the role of STEAM education in fostering creativity and problem-solving skills. Research by (Mulbar & Hasanah, 2021) similarly demonstrated the positive impact of integrating visual arts with STEM disciplines, particularly in enhancing students' engagement and critical thinking. These consistencies reinforce the value of interdisciplinary approaches in modern education (Munn, 2022). This study differs from earlier research by focusing on the specific integration of applied mathematics and visual arts. Unlike

general explorations of STEAM, this research provides detailed insights into how mathematical modeling can be translated into artistic representations, offering a unique perspective on creativity enhancement.

Previous studies often highlight challenges in balancing technical and artistic components, but this research showed that well-structured curricula could address these issues (Nazula, 2019). The inclusion of collaborative activities and real-world projects allowed students to navigate both domains effectively, bridging the gap between analytical and creative skills. The study contributes to the growing discourse on STEAM by emphasizing the importance of cultural and contextual elements. Projects such as tessellation designs inspired by cultural motifs showcased the potential of interdisciplinary education to connect academic learning with real-world and personal relevance (Ortega dkk., 2019).

The results indicate a shift in higher education toward more interdisciplinary and creative learning models. The ability to integrate applied mathematics with visual arts reflects a broader trend of blending analytical and creative skills to address complex challenges (Othman dkk., 2022). This shift aligns with the increasing demand for innovative thinkers in the workforce. The significant improvement in creativity scores suggests that traditional STEM curricula may benefit from incorporating artistic elements (Peltekova dkk., 2019). The findings highlight the limitations of siloed educational approaches and the potential of STEAM to foster more holistic learning experiences.

The success of collaborative projects underscores the importance of teamwork and peer interaction in interdisciplinary education (Poornima Varalakshmi dkk., 2023). Students' ability to co-create and exchange ideas contributed to their understanding and application of mathematical concepts, indicating the value of social learning environments. The challenges encountered, such as time management and adapting to new methodologies, highlight the need for ongoing support and refinement in implementing STEAM curricula (Purwoko dkk., 2019). These findings point to the importance of teacher training and curriculum design in achieving successful outcomes.

The research has significant implications for curriculum developers and educators in higher education. Integrating applied mathematics with visual arts can enhance creative thinking and engagement, providing students with the skills necessary for interdisciplinary problem-solving (Ramury, 2023). These outcomes emphasize the need for more STEAM-based initiatives in higher education. Students benefit from more meaningful and engaging learning experiences that connect technical concepts with practical applications (Rifandi & Laila Rahmi, 2019). This approach not only improves creativity but also prepares students for real-world challenges by fostering adaptability and innovation. These findings underscore the relevance of STEAM education in a rapidly evolving global landscape.

Educators gain insights into designing curricula that balance technical rigor with creative exploration (Rudyanto & Ghufron, 2019). By incorporating collaborative projects and real-world contexts, teachers can create learning environments that support diverse learning styles and preferences. The research highlights the importance of interdisciplinary approaches in making STEM subjects more accessible and appealing. Policymakers and institutions can use these findings to advocate for more inclusive and innovative educational models (Sakon & Petsangsri, 2021). The success of this integration demonstrates the need for investment in teacher training, resource development, and cross-disciplinary collaboration to support the widespread adoption of STEAM education.

The significant improvement in creativity scores is attributed to the interdisciplinary nature of the curriculum, which required students to apply mathematical concepts in artistic contexts. This

approach challenged students to think critically and innovatively, fostering deeper engagement and understanding (Scherbakova dkk., 2024). The role of visual arts in making abstract mathematical concepts tangible contributed to the high levels of engagement and motivation observed. Artistic projects provided students with a practical outlet for exploring mathematical ideas, making learning more relatable and enjoyable (Suchikova & Kovachov, 2024).

Collaborative activities played a crucial role in enhancing creativity and problem-solving skills (Syafe'i dkk., 2023). Group projects encouraged students to exchange ideas, consider multiple perspectives, and develop innovative solutions. This emphasis on teamwork aligns with the principles of social constructivism in education (Tamur & Juandi, 2020). The challenges faced, such as time constraints, reflect the complexity of integrating multiple disciplines into a single curriculum (Wei dkk., 2023). These limitations underscore the need for structured support and clear guidelines to ensure successful implementation. Continuous iteration and feedback are essential for overcoming these barriers.

Future research should explore the scalability of this approach across diverse educational settings. Investigating its application in non-STEM disciplines or different cultural contexts can provide a broader understanding of its potential impact on higher education (Yulianti & Ngafidin, 2022). Curriculum developers should focus on creating flexible and adaptable STEAM models that cater to varying student needs and institutional resources. Incorporating digital tools and platforms could enhance accessibility and engagement, particularly in resource-constrained environments (Yusuf & Widyaningsih, 2019).

Teacher training programs should emphasize the development of interdisciplinary teaching skills. Educators need support in designing and implementing STEAM-based curricula, including strategies for balancing technical rigor with creative exploration. Institutions should invest in interdisciplinary initiatives that foster collaboration between departments, such as STEM and arts faculties. These efforts can create a culture of innovation and interdisciplinary learning, ensuring that students are well-equipped to tackle complex, real-world challenges.

CONCLUSION

The study revealed that integrating applied mathematics with visual arts significantly enhances creative thinking in higher education, as evidenced by a 40% improvement in creativity scores among the experimental group. Unique findings included the ability of students to translate abstract mathematical concepts into tangible artistic outputs, such as fractal-based designs and tessellation art. The curriculum also fostered higher engagement and collaboration, with 85% of students actively participating in interdisciplinary projects. These results highlight the potential of STEAM-based approaches to bridge analytical and creative skills effectively.

This research contributes a novel framework for integrating applied mathematics and visual arts in a STEAM-based curriculum, emphasizing the role of collaborative and project-based learning. The use of structured interdisciplinary activities, such as geometric modeling and cultural design projects, demonstrated practical methods for enhancing creativity in technical disciplines. By combining quantitative metrics like TTCT scores with qualitative insights, the study provides actionable strategies for educators to foster innovation and engagement in higher education.

The study was limited by its focus on short-term outcomes and a single institutional context, leaving questions about long-term impacts and scalability unaddressed. The challenges of balancing technical rigor with creative exploration also suggest the need for further refinement of interdisciplinary methodologies. Future research should explore the integration of digital tools and global perspectives to enhance the applicability of STEAM approaches. Longitudinal studies

examining the sustained effects of such curricula on creativity, problem-solving, and workforce readiness will provide deeper insights into their educational value.

AUTHORS' CONTRIBUTION

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.

Author 5: Supervision; Validation.

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