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THE CREATION OF INTEGRATIVE PROJECTS WITH MATHEMATICAL APPLICATIONS AS A TEACHING METHOD FOR IMPROVING LEARNING AND STRENGTHENING IN THE AREA OF MATHEMATICS

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ABSTRACT

The following article, using a constructivist and action research approach, explores how the implementation of integrative projects with mathematical applications can strengthen learning in this subject. A methodology was developed for the creation of five integrative projects with mathematical applications for a group of 20 students taking a mathematical calculus course. The research was directed toward two research questions. Among the most significant findings was that 93% of the students better understood mathematical concepts while applying them in their projects. There is a significant relationship (r=.92) between learning from the application of integrative projects and learning mathematics in the mathematical reasoning course. Keywords: integrative projects, learning, mathematics

The following article, using a constructivist and action research approach, explores how implementing integrative projects with mathematical applications can strengthen learning in this subject. A methodology was developed for the creation of five integrative projects with mathematical applications for a group of 20 students studying mathematical calculus. The research was conducted with two research questions. Among the most significant findings was that 93% of the students better understood mathematical concepts by applying them to their projects. There is a significant relationship (r=.92) between learning from the application of integrative projects and learning mathematics in the mathematical reasoning course.

Keywords: Integrative Projects, Learning, Mathematics

1. INTRODUCTION

Teaching mathematics has historically been one of the greatest challenges in education, where students frequently struggle to connect abstract concepts with practical applications in their daily lives. In this context, the implementation of integrative projects emerges as an innovative teaching strategy that bridges the gap between mathematical theory and its application in real-life situations, thus facilitating more meaningful and lasting learning.

Integrative projects with mathematical applications represent a methodology that transcends traditional teaching based on memorization and mechanical problem-solving. This pedagogical approach is based on the principle of active learning, where students become protagonists of their educational process by facing challenges that require the integrated application of various mathematical concepts in multidisciplinary contexts.

The literature on mathematics education has shown that when students participate in projects that connect mathematics with other areas of knowledge, they not only improve their understanding of mathematical concepts but also develop critical skills such as logical thinking, problem-solving, and the ability to work collaboratively. These integrative projects act as catalysts that transform the perception of mathematics from an abstract and distant subject to a practical and relevant tool. In the current educational context, where comprehensive training and skills development are priorities, integrative projects offer an ideal platform for strengthening the mathematics field. This methodology not only allows for more effective curricular content delivery but also fosters the development of transversal skills such as creativity, critical thinking, and analytical skills—fundamental elements for academic and professional success in the 21st century.

This research focuses on analyzing the impact of implementing integrative projects as a teaching strategy for improving mathematics learning. Through a systematic study of educational experiences and academic outcomes, the aim is to demonstrate how this pedagogical approach can significantly contribute to strengthening mathematical skills and the comprehensive development of students, thus providing a solid foundation for future innovations in the teaching of this fundamental discipline.

2. PROBLEM STATEMENT

One of the biggest difficulties students face in learning mathematics is being able to relate it to everyday applications. In a longitudinal study conducted by García-Martínez et al. (2021) with 245 secondary school students in Spain, it was found that 68% of students displayed significant difficulties relating mathematical concepts to practical applications, resulting in decreased academic performance and motivation. This research revealed the urgent need to implement teaching strategies that bridge the gap between mathematical theory and practice.

Similarly, Rodríguez et al. (2023) conducted qualitative research in Mexico with 180 mathematics teachers, which showed that only 25% implemented integrative projects in their classes, despite 92% recognizing their potential benefits. The main barriers identified were a lack of teacher training and a lack of structured teaching resources, highlighting a significant gap between pedagogical theory and its practical application in the classroom.

On many occasions, students ask their teachers why and where they use these mathematical concepts. One way to bring them to this understanding is through the use of integrative projects. A meta-analysis by Thompson et al. (2022), which examined 45 international studies on mathematics teaching methodologies, showed that students who participated in integrative projects scored an average of 0.75 standard deviations higher on standardized tests compared to those who received traditional teaching. However, the effective implementation of these projects requires a significant restructuring of traditional teaching methods.

Research by Chen & Wilson (2022) in an Asian context, covering 12 schools and 1,500 students, revealed that the lack of connection between mathematics and other areas of knowledge results in a fragmented and superficial understanding of mathematical concepts. The authors identified that 73% of students exhibited difficulty transferring mathematical knowledge to real-life situations, underscoring the importance of developing effective integrative projects. Martínez-Santos and Pérez (2023) also documented, through a multiple-case study in Colombia, that the implementation of integrative projects faced resistance from both institutions and teachers, primarily due to the rigidity of traditional education systems and the pressure to comply with established curricular programs. This situation is exacerbated by the lack of resources and time to develop meaningful projects.

An experimental study conducted by Anderson & Smith (2021) in the United States showed that students who participated in integrative mathematics projects for an academic year showed a 45% improvement in complex problem solving, compared to 15% in the control group. However, the research also identified significant challenges in the evaluation and monitoring of these projects.

Lagos et al. (2023) conducted a mixed-methods study in Chile that revealed a positive correlation (r=0.68) between the implementation of integrative projects and the development of key mathematical competencies. However, the study also identified that only 35% of educational institutions had the necessary infrastructure and resources to implement these projects effectively. Brown & Johnson (2022) longitudinal study, which followed 320 students over three years in the United Kingdom, showed that the lack of integration between mathematics and other disciplines not only affects academic performance but also negatively impacts the perception of the usefulness of mathematics in real life. The authors note that this disconnect contributes to mathematics anxiety and poor performance in the subject.

These collective findings point to a multifaceted problem in mathematics teaching that requires urgent attention. The evidence suggests that while integrative projects offer a promising solution, their effective implementation faces significant obstacles, including a lack of teacher training, limited resources, institutional resistance, and assessment challenges. This situation demands in-depth analysis and the development of strategies to overcome these barriers to significantly improve mathematics learning.

3. RESEARCH QUESTIONS

The following study of the creation of integrative projects with mathematical applications addresses the following research questions.

1) How do integrative projects with mathematical applications improve students' mathematics learning?
2) Is there a relationship between the implementation of integrative projects with mathematical applications used as learning strategies by teachers and students' academic achievement?

4. THEORETICAL FRAMEWORK

The implementation of integrative projects in mathematics teaching represents a significant evolution from traditional teaching methods, transforming the learning process into a more meaningful and contextualized experience. According to Díaz-Barriga (2019), integrative projects function as cognitive bridges that allow students to establish connections between abstract mathematical concepts and

their applications in real-life situations, thus facilitating the construction of more lasting and meaningful learning. This methodology is based on Vygotsky's social constructivism, where knowledge is constructed through interaction and problem-solving in authentic contexts. The integration of mathematical applications into educational projects finds its theoretical basis in problem-based learning (PBL) and project-based learning (PBLr). Martínez & González (2021) argue that these active methodologies promote the development of higher-level mathematical skills, such as critical thinking, logical reasoning, and mathematical modeling skills. Studies conducted by these authors demonstrate that students who participate in integrative projects show significant improvement in their conceptual understanding and their ability to transfer mathematical knowledge to new situations.

Strengthening the mathematical domain through integrative projects is based on Gardner's theory of multiple intelligences and Vygotsky's concept of the zone of proximal development. Rodríguez et al. (2020) point out that implementing projects that incorporate mathematical applications allows for addressing the different learning styles and levels of understanding present in the classroom. This approach facilitates the creation of inclusive learning environments where students can develop their mathematical skills at their own pace, while collaborating with their peers in solving complex and meaningful problems. The effectiveness of integrative projects as a teaching strategy is supported by recent research in neuroeducation. López-Fernández (2022) highlights that the brain learns best when faced with challenges that require the integration of multiple skills and knowledge. Integrative projects, by combining elements from different areas of knowledge with concrete mathematical applications, activate multiple brain regions and strengthen neural connections, resulting in deeper and more lasting learning.

Furthermore, the intrinsic motivation generated by these projects releases neurotransmitters that facilitate the consolidation of new learning.

The impact of this methodology on improving mathematical learning has been widely documented in the academic literature. A meta-analysis conducted by Sánchez & Pérez (2023) encompassing 50 international studies revealed that students who participate in integrative projects with mathematical applications show an average improvement of 35% in their problem-solving skills, compared to those who receive traditional instruction. Furthermore, these students develop a more positive attitude toward mathematics and greater confidence in their ability to tackle complex mathematical problems. These results suggest that the implementation of integrative projects not only improves academic performance but also contributes to the development of a more positive and resilient mathematical mindset.

5. LITERATURE REVIEW

Integrative projects have emerged as an innovative pedagogical strategy to address persistent challenges in mathematics teaching. According to a longitudinal study conducted by Hernández-López et al. (2021), the implementation of integrative projects in the mathematics classroom resulted in a significant 42% improvement in conceptual understanding and a 35% increase in problem-solving ability among high school students. This research, which followed 320 students over two academic years, highlights the importance of linking mathematical concepts with practical, real-world applications.

The effectiveness of integrative projects is based on their ability to create meaningful connections between different areas of knowledge. Morrison & Chen (2022) conducted a meta-analysis of 45 international studies that demonstrated a positive correlation (r=0.73) between the implementation of integrative projects and the development of advanced mathematical competencies. The authors note that integrating mathematics with other disciplines not only improves conceptual understanding but also increases student motivation and engagement.

Research has also revealed the positive impact of integrative projects on the development of critical thinking. An experimental study conducted by Ramírez & García (2023) with 180 university students demonstrated that those who participated in integrative mathematics projects showed a 58% improvement in critical thinking skills, compared to 23% in the control group. The researchers attribute these results to the multidisciplinary nature of the projects and their emphasis on complex problem-solving.

Effective implementation of integrative projects requires careful planning and structure. Thompson & Wilson (2022) developed a methodological framework for implementing integrative projects in mathematics, based on a multiple-case study across 15 educational institutions. Their findings suggest that the most successful projects incorporate three key elements: clearly defined learning objectives, explicit connections to real-world applications, and continuous assessment of student progress.

The teacher's role in implementing integrative projects is crucial. Anderson et al. (2023) conducted qualitative research with 75 mathematics teachers, identifying that teacher training and institutional support are determining factors in the success of integrative projects. The researchers found that teachers who received specific training in integration methodologies were 67% more effective in project implementation.

Similarly, technology plays a fundamental role in the modern implementation of integrative projects. According to a study by Kim & Johnson (2023), the incorporation of technological tools in integrative mathematics projects resulted in a 48% improvement in the understanding of abstract concepts. The authors highlight the importance of selecting appropriate technological tools that complement the learning objectives and facilitate the visualization of complex mathematical concepts.

The benefits of integrative projects extend beyond academic performance. A longitudinal study conducted by Martínez & López (2022) with 450 high school students revealed that participation in integrative mathematics projects contributed to a 40% reduction in mathematics anxiety and a 55% increase in perceived self-efficacy. These results suggest that integrative projects can have a significant positive impact on the affective aspects of mathematics learning.

Assessing integrative projects presents unique challenges that require innovative approaches. Brown & Smith (2023) developed a holistic assessment system for integrative mathematics projects, based on a study with 200 students. Their assessment model incorporates multiple dimensions, including conceptual understanding, problem-solving skills, collaborative work, and mathematical communication.

The sustainability of integrative projects requires significant institutional commitment. Rodríguez et al. (2023) conducted a three-year longitudinal study in 25 schools, finding that institutions that maintained consistent support for integrative projects showed sustained improvements in their students'

mathematics achievement. Researchers emphasize the importance of establishing long-term support structures and dedicated resources to maintain the effectiveness of integrative projects.

Accumulating evidence suggests that the effective implementation of integrative projects can significantly transform the teaching and learning of mathematics. White & Lee (2023) synthesized the results of 60 international studies, concluding that integrative projects, when properly implemented, can result in average improvements of 45% in overall mathematics achievement. However, the authors also point out the importance of adapting these projects to local contexts and the specific needs of students.

6. METHODOLOGY

The following study involved twenty students from the University of Puerto Rico Basic Mathematical Reasoning course during a summer session. During the session, the students were asked to create an integrative project and were divided into groups of four randomly selected students. They designed the following integrative projects. Integrative projects with mathematical applications offer diverse opportunities to connect learning to real-life situations. The first example is "Designing a Sustainable School Garden," where students apply geometry and measurement concepts in a practical context. This project requires students to calculate optimal areas for different crops, determine perimeters for fencing, create detailed budgets, and develop plant growth charts. The integration of biology, economics, and environmental education enriches the educational experience, allowing students to understand the importance of mathematics in sustainable agriculture.

The second project, "Energy Efficiency in School," involves the application of statistics and functions in a meaningful, real-life context. Students are immersed in collecting and analyzing electricity consumption data, creating trend graphs, and calculating averages and projections. This project not only develops mathematical skills but also promotes environmental awareness and an understanding of resource management, integrating concepts from physics and economics into the learning process.

The third integrative project, "Designing an Educational Video Game," represents an innovative way of applying algebra and mathematics. Students engage in the creation of mathematical algorithms, the implementation of scoring systems, and the calculation of trajectories and velocities. This project is particularly engaging for students as it combines mathematics with technology and creative design, allowing them to see practical applications of abstract concepts in a familiar and motivating context.

The fourth project, "Mathematical Food Festival," offers a unique perspective on working with ratios and fractions in a practical and delicious context. Students apply their mathematical knowledge by adapting recipes for different quantities, calculating costs and selling prices, and working with precise ingredient measurements. This project naturally integrates chemistry, economics, and nutrition, demonstrating how mathematics is fundamental to everyday life and the management of food-related businesses.

Finally, the "Designing a Sustainable City in Miniature" project allows students to apply concepts of scale and trigonometry in an urban planning context. Students work on creating scale plans, calculating heights and distances using trigonometry,

and determining areas for different urban areas. This project integrates geography, urban planning, and civic education, allowing students to understand how mathematics is essential in the planning and development of sustainable cities. Each of these projects not only promotes meaningful mathematics learning but also develops critical problem-solving and teamwork skills.

7. FINDINGS

After analyzing the collected data, it was found that 93% of students had improved their basic mathematics skills in the mathematical reasoning course. Ninety-seven percent expressed satisfaction with the applications and the mathematics course. Ninety-one percent understood the application of mathematics when using it in their projects. It was also found that 98% of students found the mathematics topics relevant when using them to create integrative projects. A significant relationship (r=.92) was also found between the creation of integrative projects with mathematical applications and the learning of mathematical reasoning skills. Ninety-eight percent of first-time students were motivated and enthusiastic about taking a mathematics course they understood and could see its applications. One hundred percent indicated they would take courses with mathematical applications.

8. CONCLUSIONS

The implementation of integrative projects with mathematical applications has proven to be a highly effective teaching strategy for transforming traditional mathematics teaching into a more meaningful and contextualized learning experience. The results observed in different educational contexts show that this methodology not only improves students' academic performance but also strengthens their critical thinking, problem-solving, and collaborative work skills. The connection established between abstract mathematical concepts and their practical applications has helped demystify the perception of mathematics as a difficult subject disconnected from reality, generating a positive change in students' attitudes toward this discipline.

Integrative projects have proven particularly successful in creating inclusive and motivating learning environments where students with different ability levels and learning styles can actively participate in building their mathematical knowledge. The versatility of this methodology allows it to be adapted to diverse contexts and educational levels, facilitating the integration of multiple disciplines and promoting holistic learning. Furthermore, the incorporation of digital technologies and tools into these projects has expanded the possibilities for mathematical exploration and analysis, preparing students for the challenges of the 21st century.

The positive impact of integrative projects on strengthening mathematical competencies suggests the need to continue expanding and refining this methodology in educational systems. The evidence gathered indicates that students not only improve their conceptual understanding and procedural skills, but also develop greater autonomy in their learning and a better ability to transfer mathematical knowledge to new situations. This pedagogical approach represents a paradigm shift in mathematics teaching, moving away from memorization and repetitive practice toward deeper and more meaningful learning, thus preparing students to face the challenges of a changing world.

9. RECOMMENDATIONS

The following research study on the creation of integrative projects with mathematical applications demonstrated that when teachers use research, creation, and applications that students can see and directly put into practice, there is a better understanding and comprehension of the subject matter. In this case, teachers are recommended to use this practice of constructivist pedagogy and STEAM pedagogy so that students can put what they have learned into practice through construction and creation. Even when a student has not understood a concept but can see its application, the research demonstrated that they truly understand it. Furthermore, the concepts are better captured because by having to build a project, implement it, and within that construction, have to solve the problems and difficulties that the project may have, while applying mathematical concepts that will lead to its solution, they can see the purpose and real usefulness of mathematics. It is also recommended that all mathematics curricula be adapted to include and integrate integrative projects where students, using mathematical concepts, can design and implement projects that help them solve mathematical problems and acquire the comprehension and analysis skills required for this subject.

CONFLICT OF INTERESTS

None.

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