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Use of Digital Educational Resources for Learning Problem-Solving Competence in Mathematics

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Summary

Learning mathematics in secondary education is a recurring challenge due to low student motivation and the lack of innovative teaching strategies. In this study, the digital educational resource ZONAMATH was implemented as a methodological strategy to strengthen mathematical problem-solving competence in eighth-grade students in an educational institution in Montería, Colombia.

From a qualitative research-action approach, a series of interactive activities organized on a digital platform were designed and implemented, using tools such as Jclic, Kahoot, Genially and Educaplay. The research was developed in four phases: initial diagnosis, design of the digital resource, implementation and evaluation of the pedagogical impact. The participants were 30 eighth-grade students, who interacted with digital modules focused on solving mathematical problems through the use of educational technologies. The impact evaluation was carried out through surveys, classroom observations, and comparative analyses between the results of the diagnostic test and the final evaluation. The findings show that the use of digital educational resources increased students' motivation, participation, and academic performance in the mathematical problem-solving competition. A significant improvement in students' ability to identify, analyze, and solve mathematical problems autonomously was evidenced, which highlights the importance of integrating interactive digital tools in mathematics teaching.

Keywords: Problem solving; digital educational resources; mathematics.

Introduction

The learning of mathematics in secondary education presents significant difficulties related to low student motivation and the use of traditional methodologies focused on memorization and repetition of procedures. Various studies have shown that students have difficulty understanding and applying mathematical problem-solving strategies, which limits their ability to reason logically and make decisions in everyday situations (González & Ramírez, 2021).

One of the main factors affecting mathematics teaching is the lack of innovative strategies that allow students to visualize problems, explore different solutions, and develop flexible thinking. The traditional method, based on the mechanical application of formulas, does not favor the construction of knowledge or the development of problem-solving skills in real contexts (Valencia, 2020).

In this context, the integration of Digital Educational Resources (RED) is presented as an effective alternative to transform the teaching of mathematics, promoting more dynamic, interactive and meaningful learning. Recent studies have shown that the use of digital tools in the classroom allows students to explore mathematical concepts through simulations, games, and interactive activities, making it easier to understand procedures and apply knowledge in problem-solving (Torres & Sánchez, 2022).

This study proposes the implementation of the digital educational resource ZONAMATH as a methodological strategy to strengthen mathematical problem-solving competence in eighth grade students. The strategy is based on the use of digital tools such as Jclic, Kahoot, Genially and Educaplay, integrated into a didactic sequence designed to encourage logical reasoning and critical thinking in the resolution of mathematical problems.

This study seeks to provide evidence on the effectiveness of digital resources in the teaching of mathematics, proposing innovative strategies that favor the development of logical thinking and problem solving in an autonomous and structured way. In the next section, the theoretical approaches that underpin the research and their relationship with the teaching of mathematics through digital tools are presented.

Theoretical Approaches

The development of mathematical problem-solving competence through Digital Educational Resources (RED) is based on various theoretical approaches that explain the importance of interactive learning, logical thinking and the integration of technologies in the teaching of mathematics. The main conceptual frameworks that support this research are presented below.

1. Theory of Meaningful Learning and its Relationship to Problem Solving

Meaningful Learning, proposed by Ausubel (2000), argues that students learn better when they manage to connect new knowledge with previous structures, favoring

understanding and long-term retention. In the context of mathematics teaching, this approach implies that students must understand the meaning of mathematical concepts and apply them in solving real problems, rather than memorizing formulas without context.

From this perspective, the use of digital educational resources allows students to interact with mathematical problems in an exploratory, experimental, and contextualized way, facilitating conceptual understanding through simulations, graphic representations, and immediate feedback.

2. Math Problem-Solving Strategies

The development of mathematical problem-solving competence is based on the strategies proposed by Polya (1945), who identified four fundamental steps to solve mathematical problems:

1. Understand the problem: Identify the relevant data and the unknown.
2. Propose a plan: Select the appropriate strategy to solve the problem.
3. Execute the plan: Apply mathematical procedures in a structured way.
4. Reflect on the solution: Verify the answer and analyze other possible strategies.

The use of digital tools such as Jclic, Kahoot, and Genially allows these strategies to be applied in dynamic environments, where students can visualize problems from different perspectives, receive feedback in real time, and adjust their answers based on error analysis.

3. Integrating Technology into Mathematics Teaching

The incorporation of Digital Educational Resources (RED) in the teaching of mathematics is based on Mayer's (2005) Multimodal Learning Theory, which establishes that the combination of texts, images, interactive graphics and simulations facilitates the understanding and application of knowledge.

Recent research has shown that teaching mathematics through interactive platforms and gamified activities favors the development of logical and critical thinking in students, allowing them to explore different solution strategies and visualize mathematical concepts in a concrete and contextualized way (Torres & Ramírez, 2021).

4. Gamification and Challenge-Based Learning

Gamification in education has proven to be an effective strategy to increase students' motivation, participation and autonomy in problem solving. According to Gee (2005), incorporating play elements into the classroom allows students to explore, experiment, and solve mathematical problems in a dynamic way, promoting critical thinking and decision-making.

In this study, the digital pedagogical strategy integrates gamified activities, mathematical challenges, and virtual rewards, allowing students to progressively face problems, receive immediate feedback, and improve their performance in solving mathematical problems.

The design of the pedagogical strategy implemented in this study is based on the following theoretical principles:

1. Meaningful Learning facilitates the understanding of mathematical concepts and their application in the resolution of real problems.
2. Polya's problem-solving method allows you to structure mathematical thinking and develop analysis and solution strategies.
3. Multimodal Learning favors the construction of knowledge through the combination of graphic representations, interactive simulations and digital activities.
4. Gamification and Challenge-Based Learning increase students' motivation, commitment, and ability to face mathematical problems autonomously.

Based on these approaches, the present study analyzes the effectiveness of the digital educational resource ZONAMATH in teaching mathematical problem solving in secondary education. The following section describes the methodology used to implement and evaluate the impact of this strategy in the classroom.

Methodology

Study Design and Approach

This study adopts a qualitative approach, with an action research design, whose purpose is to analyze the impact of the use of digital educational resources (RED) on the mathematical problem-solving competence in secondary school students. Action research allows the identification of problems in teaching, the implementation of innovative strategies and the evaluation of their impact in a real classroom context (Elliot, 1993).

The digital pedagogical strategy used in this study was structured in four main phases:

1. Initial diagnosis: Evaluation of the level of mathematical problem solving of students through a diagnostic test.
2. Design and implementation of the digital strategy: Creation of the digital educational resource ZONAMATH, integrated with activities in Jclic, Kahoot, Genially and Educaplay.
3. Classroom monitoring and observation: Monitoring of students' performance on the digital platform and analysis of their interaction with activities.
4. Impact evaluation: Comparison of the results obtained before and after implementation, using surveys, final tests and analysis of interactions on the platform.

Participants

The study was conducted with 30 eighth-grade students from an educational institution in Montería, Colombia. The selection of participants was carried out through non-probabilistic intentional sampling, considering the following criteria:

- Students with difficulties in solving mathematical problems.
- Accessibility to digital tools inside and outside the classroom.
- Teachers interested in integrating digital resources into the teaching-learning process.

Data Collection Instruments

To evaluate the impact of the digital strategy on the development of mathematical problem-solving skills, the following instruments were used:

- Initial and final diagnostic test: Applied to measure changes in students' ability to solve mathematical problems after the implementation of the digital resource.
- Classroom observation: A structured observation guide was used to record student interaction and participation in digital activities.
- Student perception surveys: Applied before and after the intervention to know the opinion of students on the use of digital tools in the teaching of mathematics.
- Analysis of interactions on the digital platform: Evaluation of students' performance in gamified activities and their progress in problem solving.
- Interviews with teachers: To know their perception of the effectiveness of the digital strategy and the changes observed in students.

Implementation Procedure

The ZONAMATH digital educational resource was designed as an interactive platform, where students explored mathematical problems through thematic modules. The implementation was carried out in three pedagogical phases:

1. Exploration: Presentation of the digital resource and contextualization of the mathematical problem-solving competence.
2. Interaction and practice: Problem solving through gamified activities and strategy analysis on the digital platform.
3. Reflection and evaluation: Discussion of solution strategies, comparison of answers and application of the final test to measure the impact of the digital educational resource.

Data Analysis

The analysis of the data was carried out using content analysis techniques, organizing the information into categories related to the level of participation, the use of digital tools and the improvement in the resolution of mathematical problems. The results obtained in the initial and final diagnostic test were

compared, identifying improvements in the students' ability to analyze, pose and solve mathematical problems autonomously.

Results

Analysis of the Data Collected

The analysis of the data obtained through diagnostic tests, classroom observations, and perception surveys allowed us to evaluate the impact of the digital pedagogical strategy on the development of mathematical problem-solving competence in eighth grade students.

1. Comparison of Initial and Final Diagnostic Test Results

The tests applied before and after implementation showed a significant improvement in the students' ability to identify, pose and solve mathematical problems autonomously.

Key findings:

- Before the intervention, only 40% of the students were able to solve mathematical problems correctly.
- After implementation, 85% of students improved in identifying and applying solution strategies.
- 78% of the students showed greater accuracy in interpreting the data and setting equations to solve contextualized problems.

These results reflect that the use of digital educational resources contributed to the development of mathematical skills in students, favoring the understanding and application of problem-solving strategies.

2. Classroom Observation and Analysis of Digital Interactions

During the implementation of the strategy, classroom observation allowed us to identify changes in student attitudes and participation.

Key findings:

- Increased participation in digital activities: It was observed that 90% of students actively interacted with the ZONAMATH platform and completed the digital modules.
- Increased motivation and confidence in problem solving: Before the intervention, only 45% of students felt confident solving mathematical problems; After the digital strategy, this figure increased to 88%.
- Use of diversified strategies for problem solving: It was evident that students explored different methods of solving, promoting creativity and logical thinking.

3. Student Perception Surveys

The surveys applied at the end of the intervention allowed us to know the students' assessment of the use of digital tools in the teaching of mathematics.

Main results:

- 92% of students stated that the use of digital resources made problem-solving more interesting and understandable.
- 87% considered that gamified activities helped them to better apply solution strategies.
- 95% expressed that they would prefer to continue using digital tools to strengthen their mathematical skills.

These data reflect a high level of acceptance of digital tools and their positive impact on student motivation and learning.

4. Interviews with Teachers on the Impact of the Strategy

The interviews conducted with the teachers allowed us to know their perception of the effectiveness of the digital strategy and the changes observed in the attitude of the students.

Main comments from teachers:

- "Students demonstrated greater interest in problem solving and were more autonomous in exploring mathematical strategies."
- "The digital activities favored the understanding of mathematical concepts and improved argumentation in problem solving."
- "The use of interactive platforms allowed students to engage in the construction of mathematical knowledge in a more dynamic and effective way."

These testimonies reinforce the idea that digital pedagogical strategies favor the development of logical thinking and autonomy in the solution of mathematical problems, promoting a more meaningful and motivating learning experience.

Summary of Findings

Indicator	Initial Result	Upshot	Improvement Observed
Effective mathematical problem solving	40%	85%	Yes
Interest in problem solving	Low	High (92% acceptance)	Yes
Ability to approach and analyze data	45%	88%	Yes
Using Digital Tools for Learning	Low	High (95% acceptance)	Yes
Autonomy in problem solving	Limited	Improved	Yes

These findings reflect that the implementation of digital educational resources in the teaching of mathematical problem solving favors meaningful learning, motivation and autonomy of students. The implications of these results and their relevance to mathematics education will be discussed in the following section.

Discussion

The results obtained in this study show that the implementation of digital educational resources (RED) has generated a positive impact on the development of mathematical problem-solving competence in eighth grade students. The comparison between the initial and final diagnostic tests shows a significant improvement in the identification, approach and resolution of mathematical problems, which confirms the effectiveness of the use of digital tools in the teaching of mathematics.

From a theoretical approach, these findings support Ausubel's (2000) Theory of Meaningful Learning, which emphasizes the importance of connecting new knowledge with previous structures to achieve a deeper understanding. In this sense, the ZONAMATH platform allowed students to visualize and experience mathematical problem solving in interactive environments, which facilitated their understanding and applicability in real contexts.

Impact of Using Digital Tools on Problem Solving

One of the most relevant findings of the study was the increase in students' confidence and autonomy when facing mathematical problems. Before the intervention, only 45% of students felt confident solving mathematical problems, while after the implementation of the digital resource, this figure increased to 88%. This result is consistent with previous research that has shown that the use of digital platforms and gamified activities favors the development of logical thinking and confidence in the application of mathematical strategies (Torres & Ramírez, 2021).

In addition, the increase in student participation in digital activities shows that the use of interactive educational resources not only improves conceptual comprehension, but also fosters interest and motivation in solving mathematical problems. Before the intervention, only 40% of the students managed to solve mathematical problems correctly, while after the digital strategy, this figure rose to 85%.

These results are aligned with Mayer's (2005) Multimodal Learning Theory, which argues that the combination of texts, images, videos, and simulations improves information retention and analysis. In this study, the integration of visuals and interactive activities facilitated the understanding of abstract mathematical concepts, allowing students to explore different solving strategies.

Development of Logical Thinking and Mathematical Reasoning

Another key aspect identified in the research was the improvement in the students' ability to argue their answers and justify the procedures used in problem solving.

Before the intervention, most of the students applied strategies mechanically, without reflecting on their solution process. After the implementation of the digital strategy, 77% of the students were able to justify their answers and propose alternative solutions.

This finding coincides with the Theory of Problem-Based Learning (PBL), which holds that students learn most effectively when they face authentic problem situations, where they must analyze data, formulate hypotheses, and evaluate solutions (Polya, 1945). In this study, the use of gamified activities and mathematical simulations allowed students to develop more structured and flexible mathematical thinking, exploring different strategies to solve the problems posed.

Challenges and Limitations

While the results reflect a positive impact on the teaching of mathematical problem solving, the study also identified challenges and limitations in the implementation of the digital strategy:

1. Digital divide: Although most students managed to interact with the digital platform, some faced difficulties in accessing electronic devices outside the classroom, suggesting the need for complementary strategies to ensure equity in learning.
2. Learning curve in the use of digital tools: It was evident that a group of students had initial difficulties in navigating and using the platform, which highlights the importance of including a previous training phase to optimize the learning experience.
3. Cognitive load: Some students stated that the amount of information on the digital platform could be overwhelming, indicating the need for a progressive and structured organization of digital content.

Implications for Educational Practice

The findings obtained in this study have important implications for the teaching of mathematics in secondary education. It is recommended that educational institutions:

1. Incorporate digital tools in the teaching of mathematical problem solving, ensuring that students can access interactive resources that facilitate the exploration and application of mathematical strategies.
2. Design gamified activities and problem-based learning strategies, promoting active participation and the development of logical thinking.
3. Train teachers in the integration of technology in the classroom, ensuring that they have the necessary skills to guide students in the use of digital platforms.
4. Guarantee equitable access to technology, implementing strategies that reduce the digital divide and facilitate the integration of digital tools inside and outside the classroom.

Finally, future research could expand this analysis through longitudinal studies that evaluate the sustained impact of the use of digital tools in mathematics teaching. In addition, it would be relevant to explore how the incorporation of artificial intelligence and augmented reality environments could further enhance the learning experience in solving mathematical problems.

Conclusions

The findings obtained in this study confirm that the implementation of digital educational resources (RED) in the teaching of mathematical problem solving significantly improves student performance, motivation and autonomy in the development of mathematical competencies. The ZONAMATH platform, integrated with digital tools such as Jclic, Kahoot, Genially, and Educaplay, allowed students to interact with mathematical concepts in a dynamic and meaningful way, facilitating the construction of knowledge through exploration and practical application.

From a theoretical approach, these results support Ausubel's (2000) Theory of Significant Learning, which emphasizes the importance of relating new learning to previous knowledge in order to achieve a deeper understanding. Likewise, Mayer's (2005) Multimodal Learning Theory highlights that the combined use of texts, images, simulations and interactive activities favors the retention and analysis of information.

At the methodological level, the research showed that the use of digital pedagogical strategies increased the active participation of students in solving mathematical problems, promoting the development of logical thinking and mathematical argumentation. The data shows that 85% of students improved their problem-solving performance, and 92% stated that the use of digital tools made the subject more interesting and accessible.

However, the study also identified some challenges in the implementation of the digital strategy, such as the gap in access to technology, the need for training in digital tools for teachers and students, and the importance of progressively structuring the amount of information available on the platform.

From a practical perspective, these findings suggest that educational institutions should:

1. Incorporate interactive digital platforms in the teaching of mathematical problem solving to encourage the exploration and application of strategies.
2. To design didactic strategies that combine gamification and problem-based learning, promoting motivation and autonomy in students.
3. Train teachers in the use of digital tools, ensuring that they can effectively integrate technology into mathematics teaching.
4. Reduce the digital divide, ensuring that all students have access to the technologies necessary to strengthen their learning.

Finally, future research could explore the long-term impact of using digital tools on teaching mathematical problem-solving. It would also be pertinent to analyze how

the incorporation of artificial intelligence and augmented reality can further enhance the learning experience, allowing students to experience new forms of interaction and analysis in the development of logical-mathematical thinking.

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