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Enhancing the Understanding of the Concept of Function through Integrated Visual and Experiential Approaches

Original scientific paper

Ismet Temaj[1], Senad Orhani[2], Esma Canhasi-Kasemi[1]

[1]Faculty of Education, University of Prizren "Ukshin Hoti", Prizren, Kosovo
[2]Faculty of Education, University of Prishtina "Hasan Prishtina", Prishtina, Kosovo

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Abstract

This paper aims to explore the impact of integrated visual and experiential approaches in improving the understanding of the concept of function among lower and upper secondary school students. Function, a fundamental and often abstract mathematical concept, challenges many students. The study aims to show that the integration of visual tools, such as graphs and diagrams, together with experiential activities, can facilitate deeper visualization and understanding of function, as well as improve performance in solving mathematical problems. The methodology used in this study is quasi-experimental with qualitative and quantitative data, including controlled analysis with the experimental group and the control group. The sample consists of 120 lower and upper secondary school students, randomly divided into two groups: one group that was exposed to traditional approaches and another group that used visual and experiential approaches. The data collection instruments included structured questionnaires, pre-and post-tests, and observations during the teaching process. The results showed a significant improvement in the conceptual understanding of the function among students who used visual and experiential approaches, compared to those who used traditional methods. Furthermore, students in the experimental group showed a higher level of engagement and motivation during the learning process. These findings suggest that integrated visual and experiential approaches are effective tools to facilitate understanding and improve learning outcomes in mathematics.

Keywords: *Experimental Approach, Function, Mathematics Education, Practical Experiments, Visual Approach*

Mathematics is one of the most fundamental disciplines for the development of analytical skills and logical thinking in students. Within this discipline, the concept

Correspondence to: Senad Orhani, Faculty of Education, University of Prishtina "Hasan Prishtina", Prishtina, Kosovo. Email:senad.orhani@uni-pr.edu

of function plays a critical role, serving as a basis for the development of further knowledge in other areas of mathematics and science. Through function, students learn to understand dependencies and relationships between variables, thus building skills for solving complex problems in fields such as applied mathematics, physics, economics, and engineering. However, although the function is an essential concept, it is often difficult for many students to master due to its abstract and complex nature (Skovsmose, 2020).

Recent studies have shown that improving understanding of abstract concepts, such as function, can be achieved through integrated visual and experiential approaches. Visual approaches, which include the use of graphs, diagrams, and other visual aids, help students create a clearer picture of the interdependencies between variables. These approaches make it easier to understand complex relationships and fulfill the need for a more tangible approach to abstract concepts (Demitriadou et al., 2020). In addition to visual approaches, experiential methods have also proven to be very effective in improving understanding. Through experimentation and practice, students can see how mathematical functions apply in the real world, thus strengthening the connection between theory and practice (Kramarenko, Pylypenko, & Kostiukevych, 2020). The integration of visual and experiential approaches, the use of augmented and virtual reality, and interactive approaches that link theory and practical applications have proven to be more beneficial for the deep acquisition of mathematical knowledge (Demitriadou et al., 2020; Abrahamson et al., 2020; Kramarenko et al., 2020).

Problem Identification

In traditional mathematics education, the function is often taught through textual and numerical methods, relying on formal and abstract solutions of equations. This method often fails to create a strong connection between the concept of function and its real-world applications. Furthermore, students often have difficulty visualizing the interdependencies of variables and interpreting graphs that describe functions. In this context, many researchers have argued that traditional methods are not sufficient to develop a deep and sustainable understanding of function (Skovsmose, 2020).

Visual and experiential approaches have been proven to be effective in increasing student motivation and engagement in the learning process. Using technologies such as augmented reality and mathematical software, these approaches provide opportunities to explore solutions to mathematical problems more interactively and dynamically (Kramarenko et al., 2020). One of the main benefits of these methods is their ability to improve not only conceptual understanding but also students' practical skills to solve complex mathematical problems (Abrahamson et al., 2020).

Purpose of the Study

The main purpose of this research is to examine the impact of integrated visual and experiential approaches in improving the understanding of the concept of function among middle and high school students. The function is an abstract concept that often creates challenges for students, and this study is intended to demonstrate that the integration of visual approaches, such as graphs and diagrams, together with experiential approaches, can improve not only the visualization of the function but also the performance in solving complex mathematical problems. The study also aims to compare these methods with traditional teaching approaches and to determine whether visual and experiential approaches improve student engagement and motivation in the learning process. Finally, the aim is to provide recommendations on the wider use of these methods in mathematics education.

Research Questions

1. How effective is the use of integrated visual and experiential approaches in improving the understanding of the concept of function among middle and high school students?
2. How does the improvement in understanding the concept of function differ between students who follow visual and experiential approaches (experimental group) and those who follow traditional teaching methods (control group)?
3. How do visual and experiential approaches affect student engagement and motivation during the mathematics learning process, compared to traditional approaches?
4. What do modern technologies, such as augmented reality and digital simulations, contribute to improving

students' understanding and performance in mathematics through visual and experiential approaches?
5. Is there any connection between the use of visual and experiential approaches and improving students' performance in solving complex mathematical problems?

Research Hypothesis

Hypothesis 1: The use of integrated visual and experiential approaches has a positive impact on improving the understanding of the concept of function among middle and high school students.

Hypothesis 2: Students who follow visual and experiential approaches (experimental group) show greater improvement in understanding the concept of function compared to students who follow traditional teaching methods (control group).

Hypothesis 3: Visual and experiential approaches will increase student engagement and motivation during the mathematics learning process more than traditional approaches.

Hypothesis 4: Modern technologies, such as augmented reality and digital simulations, contribute to improving students' understanding and performance in mathematics through visual and experiential approaches.

Hypothesis 5: There is a positive correlation between the use of visual and experiential approaches and improved student performance in solving complex mathematical problems.

Literature Review

A function is a fundamental mathematical concept that relates variables and finds widespread use in fields such as physics, economics, and engineering. Through functions, students learn to model complex relationships, but their abstract nature often presents challenges to understanding (Verschaffel et al., 2020). These challenges are especially evident when formal definitions and applications are not directly related to students' everyday experiences. The use of visual approaches, such as graphs and diagrams, helps students visualize relationships between variables and more easily understand functional interdependencies (Zulnaidi et al., 2020). Interactive simulations significantly increase the acquisition of concepts and skills for solving complex problems (Orhani & Çeko, 2021). Dynamic visualizations are particularly useful as they allow students to explore the changes in functions in real-time (Kohen et al., 2022). On the other hand, experimental approaches connect theory with practice, making it easier for students to understand and apply functions in real situations (Struyf et al., 2019). The inclusion of real-world applications, such as economic or scientific models, helps students understand the intricacies of functions and develop problem-solving skills (Subramanian & Budhrani, 2020).

Advanced technologies, such as augmented reality (AR) and digital simulations, have revolutionized the way mathematics is learned. AR applications allow students to interact with mathematical concepts and visualize interdependencies between variables, significantly improving understanding and performance (Demitriadou et al., 2020; Amores-Valencia et al., 2023). These technologies also reduce math anxiety and increase student motivation (Chen, 2019).

Traditional methods focus on numerical and algebraic problem-solving and are effective for teaching standard procedures (Papadakis et al., 2021). However, they often fail to help students visualize complex relationships between variables (Strohmaier et al., 2020). In contrast, visual and experiential approaches offer a more interactive way to understand concepts, including graphics, simulations, and hands-on experiments (Rodríguez-Martínez et al., 2020). Visual and experiential approaches have been shown to significantly increase student motivation and engagement. When students engage in activities that involve visualizations and experiments, they are more likely to grasp concepts and develop complex problem-solving skills (Doumanis et al., 2019; Dubovi, 2022). Engaging in these activities also helps reduce math anxiety and improves self-confidence in problem-solving (De Loof et al., 2021). These findings suggest that integrating visual and experiential approaches, along with modern technologies, significantly improves the quality of teaching and learning of functions in mathematics.

Methodology

Research Design

This study uses a quasi-experimental design with a control group and an experimental group to measure the impact of integrated visual and experiential approaches on improving understanding of the concept of function. The quasi-experimental design was chosen because it allowed for comparisons between groups of students exposed to different teaching methods. The experimental group was exposed to visual and experiential approaches, which included the use of graphs, visual simulations, and hands-on experiments. The control group, on the other hand, followed traditional teaching methods, where the function was taught primarily through lectures and numerical exercises without the aid of visual approaches. The quasi-experimental design includes pre- and post-tests to measure improvement in mathematical function understanding and problem-solving performance. By using a control and experimental group, the study can compare the differences in student performance and engagement across two different teaching methods, providing a clear insight into the effectiveness of the new approaches.

Research Participants

The sample consists of 120 students from lower and upper secondary schools, randomly divided into two groups: an experimental group with 60 students and a control group with 60 students. Participants were selected from several lower and upper secondary school students in the Municipality of Prizren from the Republic of Kosovo, taking into account a random selection to avoid any influence of external factors. Participants are students who follow the subject of mathematics from grades 6-12 as part of their curriculum, and their level of knowledge in mathematics ranges from low to high, including prior knowledge of functions. Participants were included in this study for 4 weeks. During this period, students in the experimental group were exposed to visual and experimental approaches through graphs, simulations, and practical activities, while the control group followed traditional teaching methods.

Data Collection Instruments and Analysis

The study used three main instruments for data collection: pre-and post-tests to measure initial knowledge and improvement in the concept of function, questionnaires to assess student engagement and motivation after the intervention, and classroom observations to monitor interactivity and involvement in practical activities. These instruments provided a comprehensive analysis of the impact of visual and experiential approaches on the learning process.

The collected data were analyzed using quantitative and qualitative statistical methods. T-test analysis was used to compare the results of the experimental and control groups regarding the difference in performance and understanding of the concept of function. In addition, descriptive qualitative analysis was used to evaluate the comments and reactions of the students, as well as to examine the data collected through observations. This type of analysis provided a deeper insight into the teaching process and helped in understanding the motivation and engagement of the students when using the new teaching methods.

Research Ethics and Limitations

In this study, all ethical standards were respected, ensuring voluntary participation, full information about the purpose of the research, institutional approvals, and maintaining the anonymity and confidentiality of participants. Limitations include the relatively small number of participants, the short 4-week intervention period that limits long-term evaluation, and the influence of external factors, such as teaching style or individual student motivation, that may have affected the results.

Results

This chapter presents the results of research on the impact of visual and experiential approaches in improving understanding of the concept of function. These results were collected through pre- and post-tests, questionnaires, and student observations during the intervention. The comparison between the experimental group and the control group shows the effectiveness of the new teaching approaches to traditional methods.

Test Results

This section presents the results of the pre-and post-tests performed by the students in the experimental and control groups. The tests were designed to measure the initial level of knowledge of the concept of function and to compare the improvements after the intervention with the visual and experimental approaches. Next, we analyze the descriptive statistics between the pre-and post-test scores:

Table 1.

Descriptive Statistics from Test Results

Test	Mean	Median	SD	Minimum	Maximum
Pre-Test	53.43	56.00	21.60	22.00	84.00
Post-Test	66.90	68.00	23.23	35.00	100.00

Based on the test results, we analyze the effect of the intervention based on visual and experimental approaches to understanding the concept of function in mathematics. The statistical results of the pre-and post-intervention tests can be interpreted in the context of this paper as follows:

After the intervention, the results show a significant improvement in students' performance in understanding the function. The mean increased from 53.43 in the pre-test to 66.90 in the post-test, an improvement of 13.47 points, while the median increased from 56.00 to 68.00, indicating that most students experienced improvement. The increase in the minimum score from 22.00 to 35.00 and the maximum score from 84.00 to 100.00 suggests that the improvements included all levels, from those with difficulties to high-performing students.

A slight increase in the standard deviation (from 21.60 to 23.23) reflects the variation in the results, indicating that the intervention affected students differently. These results support the idea that visual and experiential methods improve the understanding and application of mathematical concepts.

We are further analyzing the results between the pre-and post-test scores:

Table 2.

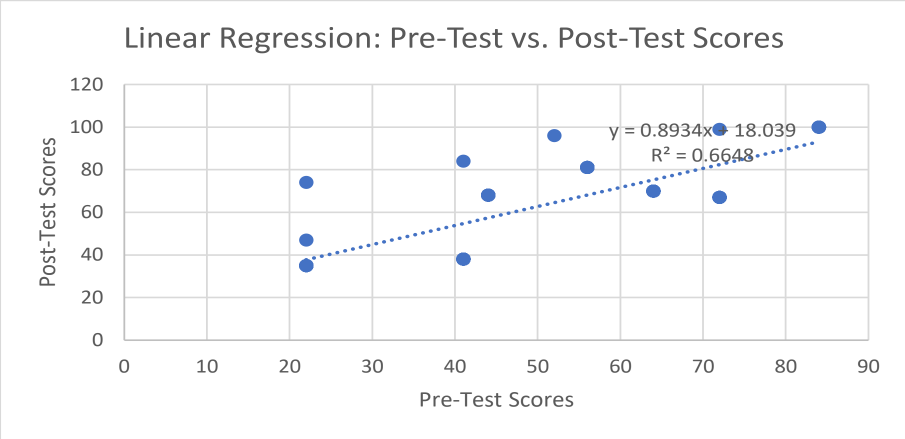
Analysis of Test Results

Statistics	Value
Paired t-test statistic	5.17
Paired t-test p-value	0.00
Cohen's d (effect size)	0.63
Mean Percentage Improvement (%)	27.89

The results of the statistical analysis clearly show the effectiveness of the intervention in improving student outcomes. The paired t-test value (5.17) and the very low p-value .00 confirm that the difference between pre-and post-intervention scores is statistically significant and not random. The effect size (Cohen's d = .63) indicates a strong medium effect, highlighting the positive impact of the intervention. The average improvement of 27.89% reflects a significant improvement in performance and the level of acquisition of mathematical concepts. These results indicate that the intervention has significantly affected the academic outcomes and development of students.

Next, we are analyzing the linear regression between the pre-and post-test scores:

Figure 1.
Linear Regression: Pre-Test vs. Post-Test Scores



Linear regression analysis between pre and post-test scores shows a positive relationship between these variables. The regression line (equation:) suggests that for every 1-point increase in the pre-test, an average increase of .89 points is expected in the post-test. The intercept (18.039) indicates the predicted post-test scores when the pre-test scores are zero, although a zero score is somewhat unrealistic. The value of (.6648) indicates that about 66.48% of the variation in post-test scores is explained by the pre-test scores, suggesting a moderate to strong linear relationship. However, the not very high value indicates that factors other than pre-test scores may influence post-test scores. Overall, the analysis confirms that pre-test performance is a good indicator of post-intervention outcomes, but not the only influencing factor.

Results from the Observation

Systematic observations were conducted during the intervention to monitor students' behavior and engagement in the use of visual and experiential tools. These results are summarized in the table below:

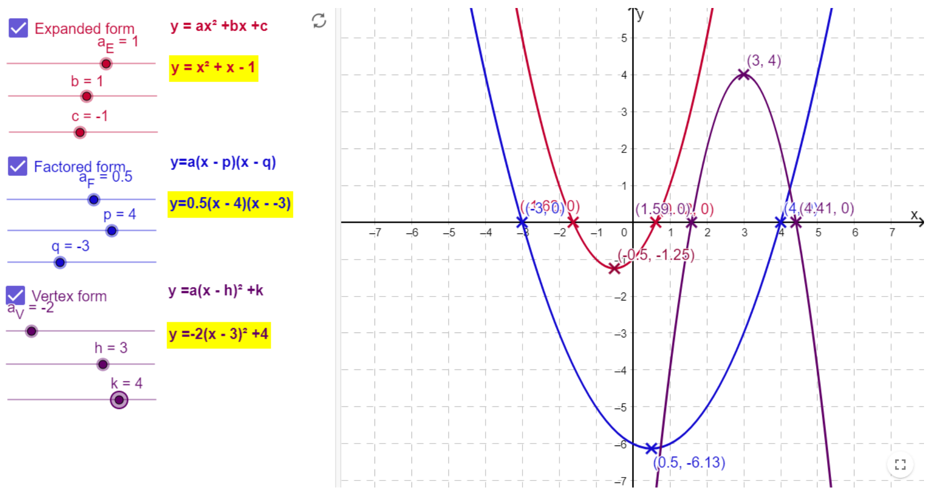
Table 3.
Observational Results for the Experimental Group

Criterion	Description	Assessment
Engagement in learning	The student is focused and active in the learning process, participates in discussions, and asks the teacher for clarification when necessary.	4.3
Use of visual aids	The student uses graphs, diagrams, and simulations to explain and derive concepts of functions. It can create graphics precisely.	4.2
Using experimental approaches	The student engages in practical experiments and understands the connection between practical results and mathematical theory.	3.9
Cooperation with classmates	The student works effectively with others, shares ideas, discusses solutions, and supports classmates in learning activities.	4.4
Understanding the concept of function	The student shows improvement in understanding the concept of function, can identify dependent and independent variables, and explain relationships.	3.5
Applying knowledge to problem-solving	The student correctly applies knowledge of functions to solve complex problems using visual and experimental tools.	3.7
Explanation and reflection on experiments	The student can analyze and explain the results of practical experiments, relating the results to the theory of function.	4.0
Motivation to learn	The student is motivated to acquire new knowledge and improve skills, showing persistence in facing learning challenges.	4.1

The results collected from the student observation indicate a high overall performance in the use of visual and experimental approaches. The results show that students showed high engagement during the intervention, with an average rating of 4.3 out of 5.0, reflecting active participation and focus on learning. Visual approaches were positively rated with 4.2 out of 5.0, aiding in the understanding and use of graphs, diagrams, and simulations to explain the concepts of functions. Involvement in practical experiments was rated with 3.9 out of 5.0, suggesting potential for improvements in the implementation of experimental methods. Collaboration between students was rated highly, with 4.4 out of 5.0, indicating successful group interaction and sharing of ideas. Understanding functions (3.5 out of 5.0) and their application in problem-solving (3.7 out of 5.0) show moderate improvement, suggesting the need for more practice for deeper understanding and independent application. Students were rated 4.0 out of 5.0 for their skills in analyzing and explaining experimental results, indicating a good connection between theory and practice. Motivation to learn (4.1 out of 5.0) was high, reflecting the positive impact of visual and experiential approaches in increasing engagement and interest in learning.

Figure 2.

Simulation of Functions in GeoGebra



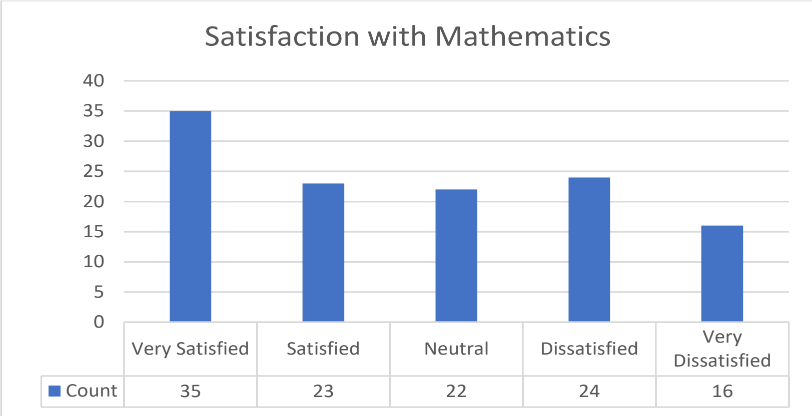
In this video, students had the opportunity to explore quadratic functions in three different forms: expanded, factored, and vertex using augmented reality (AR) through the GeoGebra software. Using this simulation, they observed how each form represents the function and how changing the parameters affects the graph.

The augmented reality (AR) and visual simulation activity allowed students to manipulate the parameters of quadratic functions and observe changes in the characteristics of the graphs in real-time. Students learned how the coefficients in the expanded form affect the overall shape of the graph, how in the factored form is related to the intercepts of the axis , and how the and parameters in the vertex form affect its position. This interactive activity helped students better visualize and understand the relationships between the parameters of the function and the shape of the graphs, transforming abstract concepts into easy-to-understand experiences. The teacher's assistance in relating each form of the function to its characteristics provided a deep and integrated understanding of various mathematical and practical applications.

Results from Questionnaires

The results of the questionnaires showed that the students in the experimental group experienced a significant improvement in their understanding of functions and motivation to learn mathematics. For a more detailed analysis of the questionnaire results, we will examine the distribution of responses for each category, analyzing the main trends and extracting statistics for each important indicator.

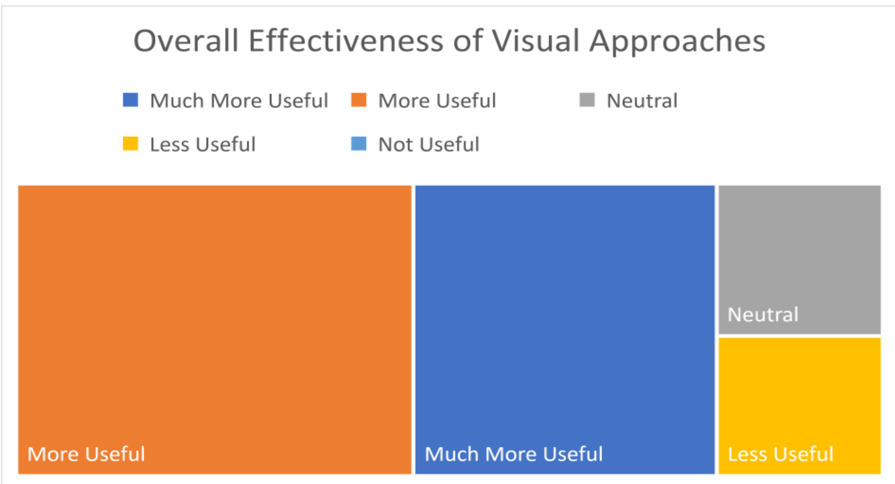
Figure 3.
Satisfaction with Mathematics



Regarding satisfaction with the mathematics subject, out of a total of 120 students, 35 students are very satisfied, 23 students are satisfied, 22 students feel neither satisfied nor dissatisfied, 24 students are dissatisfied, and 16 students are very dissatisfied. This distribution shows a diversity in the level of satisfaction with mathematics. Although there is a large number of students who are satisfied or very satisfied (48%), there is also a significant proportion who are dissatisfied (33%). This suggests that there is potential for improvement in the way mathematics is presented and taught.

The results show a positive impact of visual and experimental approaches in the teaching and learning process of mathematics. About 60% of students reported continuous or frequent use of visual aids, highlighting the successful integration of these tools in the lessons. Graphs and diagrams were considered very helpful by 68% of students, highlighting the importance of visualization in understanding complex concepts. After the intervention, 62% of students felt more able to understand the relationships between variables, and 69% reported that practical experiments were useful or very useful. Engagement was high for 53% of students, however, 27% reported low engagement, suggesting the need for improvement in the approaches used. Motivation for mathematics increased for 52% of students, while 63% felt more confident in solving problems, indicating improvement in practical and theoretical skills. However, a portion of students reported a lack of impact in some aspects, suggesting the need for more personalized approaches to maximize benefits for all.

Figure 4.
Use of Visual Aids Approaches



The results show a positive perception of visual and experiential approaches compared to traditional teaching methods. Around 80% of students (97) reported that these approaches are more useful, supporting their greater involvement in the learning process. Also, 62% of students (74) expressed the desire to integrate these approaches into other subjects, highlighting their potential to improve teaching and learning in different fields of study.

Table 4.
Results from Correlation

Category	Satisfaction with Math	Use of Visual Aids	Effectiveness of Diagrams	Understanding Variables	Practical Experiments	Engagement Level	Confidence in Problem Solving	Effectiveness of Visual Approaches
Satisfaction with Math	1.00	0.98	0.90	0.31	0.33	0.49	0.45	0.60
Use of Visual Aids	0.98	1.00	0.85	0.35	0.43	0.59	0.60	0.66
Effectiveness of Diagrams	0.90	0.85	1.00	0.26	0.25	0.11	0.29	0.45
Understanding Variables	0.31	0.35	0.26	1.00	0.93	0.54	0.65	0.92
Practical Experiments	0.33	0.43	0.25	0.93	1.00	0.62	0.87	0.93
Engagement Level	0.49	0.59	0.11	0.54	0.62	1.00	0.73	0.76
Confidence in Problem Solving	0.45	0.60	0.29	0.65	0.87	0.73	1.00	0.82
Effectiveness of Visual Approaches	0.60	0.66	0.45	0.92	0.93	0.76	0.82	1.00

Correlation analysis shows the strong positive impact of visual and experiential approaches on students' enjoyment, understanding, and engagement in mathematics. The very high correlation between the use of visual aids and students' enjoyment (.98) highlights the importance of graphs and diagrams in creating an engaging and motivating environment for learning abstract concepts. Similarly, a significant correlation (.93) between experiential approaches and the ability to understand variables suggests that practical applications help students connect theory to the real world, improving their understanding of functions. The positive correlation between engagement and self-confidence in problem-solving (.73) indicates that these approaches increase not only motivation but also students' confidence in their abilities. These findings suggest that the wider use of visual and experiential approaches can significantly improve teaching and learning in mathematics and other subjects.

In the open-ended question, students highly valued the use of visual and experiential approaches in teaching, emphasizing that these methods made complex concepts more understandable, especially when graphs and diagrams were included in the explanations. Practical experiments and simulations helped students see theories in action, making the learning process more tangible and fun. These approaches also increased engagement and motivation, making learning more practical and interactive. On the other hand, some students noted some shortcomings, such as the need for more time and preparation for these approaches, the difficulty in adapting to non-traditional methods, and the potential interruptions during the use of technology that negatively affected concentration and understanding of the material.

Discussion

The results of the study show that visual and experiential approaches have a significant impact on improving the understanding of the concept of function and increasing student engagement and motivation. Students in the experimental group, who used these approaches, showed significant improvements compared to the control group that used traditional methods. Visual approaches, such as graphs and diagrams, helped to visualize the relationships between variables, supporting the findings of Demitriadou et al., (2020). Practical experiments facilitated the connection between theory and real-world applications, a conclusion consistent with the studies of Kramarenko, Pylypenko, & Kostiukevych (2020). The use of modern technologies, such as augmented reality (AR) and digital simulations, significantly improved student engagement and motivation, supporting the results of the studies of Demitriadou et al. (2020) and Abrahamson et al. (2020). Statistical results showed significant improvements in student performance in the experimental group, supported by studies by Zulnaidi et al. (2020), which show that interactive graphs and simulations increase the acquisition of concepts such as functions in mathematics education. In addition, these approaches helped overcome the difficulties that students encounter in visualizing dependencies between variables, as also highlighted by Skovsmose (2020). The study reinforces that the integration of visual and experiential approaches can significantly increase the quality of teaching and learning in mathematics, creating a more engaging and effective experience for students.

The study provided answers to the main research questions, confirming the positive impact of visual and experiential approaches on the teaching and learning process, with an average improvement from 53.43 to 66.90 (27.89%), supporting the findings of Demitriadou et al. (2020) and Kramarenko et al. (2020). Students in the experimental group showed greater improvement compared to the control group, reinforcing the effectiveness of these approaches (Abrahamson et al., 2020). The approaches significantly increased student engagement and motivation (mean rating 4.3 out of 5.0), in line with Doumanis et al. (2019). Technologies such as augmented reality and digital simulations contributed to improving the visualization of relationships between variables and performance, supporting Amores-Valencia et al. (2023). Linear regression analysis showed a positive relationship between approaches and performance in solving complex problems, with a strong medium effect size (Cohen's d = .63), as confirmed by Zulnaidi et al., (2020). These results confirm the effectiveness of visual and experiential approaches in improving understanding, engagement, and performance in mathematics.

The study supports all the main hypotheses, confirming the positive impact of visual and experiential approaches in teaching. Hypothesis 1 shows that the use of visual and experiential approaches significantly improves the understanding of the concept of function, matching the findings of Demitriadou et al., (2020) and Kramarenko et al., (2020). Hypothesis 2 confirms that students in the experimental group showed greater improvement compared to the control group, supported by Kramarenko et al., (2020). Hypothesis 3 shows that these approaches increase student engagement and motivation, as suggested by Doumanis et al., (2019). Hypothesis 4 confirms that modern technologies, such as augmented reality and digital simulations, contribute to improving student understanding and performance, in line with Amores-Valencia et al., (2023). Hypothesis 5 supports a positive correlation between the use of these approaches and complex problem-solving skills, as shown by the results of Zulnaidi et al., (2020). These results confirm the effectiveness of visual and experiential approaches in improving understanding, engagement, and performance in mathematics education.

Limitations and Practical Implications

Although the results showed a positive impact of visual and experiential approaches, the main limitations include the short intervention period, which limits the assessment of long-term impacts, and the influence of external factors such as teaching style or individual student motivation. A more detailed study is recommended for future studies. Longer intervention period to analyze long-term effects; and a deeper exploration of modern technologies, such as augmented reality and simulations, to maximize benefits in mathematics education.

The study provides strong evidence that future researchers can use these results to elaborate on the effectiveness of visual and experimental approaches in improving function understanding, showing a significant improvement in performance and increasing student engagement and motivation. The use of modern technologies, such as augmented reality and digital simulations, has proven particularly effective in visualizing complex relationships between variables while linking theory with practical applications has helped students apply knowledge to real-world situations. These results not only provide a powerful methodological model, but also suggest a basis for future researchers to explore long-term impacts, extend applications to other disciplines, and further improve technologies and approaches used in mathematics education.

This study enriches the existing literature by providing empirical evidence for the effectiveness of visual and experiential approaches in improving understanding and engagement in mathematics while suggesting the use of modern technologies such as augmented reality and digital simulations to address conceptual challenges. The results may help solve practical problems in other countries, such as lack of student engagement and difficulties in acquiring abstract concepts, by providing a model for introducing interactive approaches and innovative technologies in mathematics education.

Conclusion

This study evaluated the impact of visual and experimental approaches on improving the understanding of function in high school students. The results showed a significant improvement in the performance of the experimental group, with an increase in the mean from 53.43 to 66.90, confirming the effectiveness of these approaches in the acquisition of new knowledge. Visual approaches, through graphs and simulations, helped students visualize complex relationships between variables, while practical experiments connected theories with real-world applications, improving complex problem-solving skills.

The use of modern technologies, such as augmented reality (AR), increased students' engagement and interaction with mathematical concepts, making them more tangible and understandable. These results suggest that visual and experiential approaches are effective methods for improving understanding, engagement, and motivation in mathematics. The study highlights the need to integrate these modern approaches and technologies into mathematics teaching to make abstract concepts more tangible and meaningful for students.

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