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# Fun Strategies for Learning Mathematics: Exploring the Potential of Combinatorial Game Theory in Discrete Mathematics

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**ABSTRACT**

**Purpose of the study:** This study aims to examine the effectiveness of using combinatorial game theory in discrete mathematics learning to improve students' understanding and interest in learning.

**Methodology:** Using the Mixed Methods approach, quantitative data were collected through a quasi-experimental design with a pretest-posttest control group, while qualitative data were obtained through interviews and observations. The sample consisted of 60 grade XI students divided into experimental and control classes.

**Main Findings:** The results of the analysis showed that the average gain score of students' conceptual understanding in the experimental class (0.68) was significantly higher than the control class (0.32) with a t-test significance value of 0.001 ($p < 0.05$). In addition, the motivation questionnaire showed an increase in the average score from 2.9 to 4.1 on a Likert scale of 1–5.

**Novelty/Originality of this study:** Qualitative findings reinforce that game-based strategies encourage active participation, collaboration, and positive perceptions toward discrete mathematical theory.



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## 1. INTRODUCTION

Mathematics, particularly Discrete Mathematics, is often perceived by students as abstract, complex, and disconnected from daily experiences. Unlike continuous mathematics, discrete mathematics involves structures such as sets, graphs, and algorithms, which require a high level of logical reasoning and precision [1]-[4]. These characteristics can be challenging for students who are more accustomed to procedural and calculation-based learning [5]-[7]. Moreover, topics like combinatorics, graph theory, and logic demand not only conceptual understanding but also the ability to apply abstract thinking to unfamiliar problem contexts [8]-[10]. This has led to low engagement and a general lack of enthusiasm for discrete mathematics in secondary education.

To address these challenges, various innovative strategies have been explored to make mathematics more relatable and engaging. One such promising approach is the use of combinatorial game theory—a branch of discrete mathematics that analyzes strategies in structured, rule-based games [11], [12]. Previous studies have highlighted the potential of game-based learning to increase student motivation and improve conceptual understanding [13]-[15]. Games like Nim, Tic-Tac-Toe, and Sprouts have been used successfully to teach logical reasoning, pattern recognition, and strategic thinking—skills that are central to discrete mathematics [16]-[18]. Research by Socrates et al., [19] and Lavega et al., [20] shows that students exposed to game-theoretic learning environments demonstrate better problem-solving abilities and greater enthusiasm for mathematics.

Although numerous studies have explored the use of game theory in mathematics education, most of them focus on general mathematics or higher education contexts. There is a lack of specific research targeting the application of combinatorial game theory in teaching discrete mathematics at the secondary school level [21]-[23]. Furthermore, few studies have examined how such games can be systematically integrated into the curriculum to support cognitive development and long-term interest in mathematical reasoning.

The novelty of this study lies in its unique focus on the systematic application of combinatorial game theory in Discrete Mathematics learning at the secondary education level, an approach that has rarely been explored in depth in previous literature. Unlike previous studies that tend to focus on the use of game theory in general mathematics or higher education contexts, this study offers a new contribution by integrating logic-based game strategies and discrete structures into the secondary school curriculum. This approach is not only designed to improve conceptual understanding, but also aims to foster students' long-term interest and critical thinking skills in materials that are generally considered abstract and difficult.

This study aims to explore how combinatorial game theory can be effectively used to inspire students to enjoy and better understand discrete mathematics in a secondary education setting [24], [25]. The urgency of this research lies in the increasing demand for educational methods that not only convey content knowledge but also develop critical thinking and problem-solving skills—competencies that are crucial in the 21st-century digital era. By embedding strategic games within discrete mathematics learning, this research hopes to provide a practical, engaging, and intellectually stimulating alternative to traditional methods. The expected outcome is a learning model that transforms discrete mathematics from a perceived obstacle into a source of curiosity, challenge, and enjoyment for students [26], [27].

## 2. RESEARCH METHOD

### 2.1. Research Design

This study uses a Mixed Methods approach, which is a combination of quantitative and qualitative approaches. This approach was chosen to gain a comprehensive understanding of the effectiveness of combinatorial game strategies in Discrete Mathematics learning. Specifically, this method allows researchers to analyze the impact of game-based learning strategies on conceptual understanding, learning motivation, and student perceptions through a combination of numerical and narrative data. The quantitative design used is a quasi-experiment with a pretest-posttest control group pattern [28]-[30]. Two classes were used, namely the experimental class that received game theory-based learning, and the control class that received conventional learning. Meanwhile, the qualitative approach is exploratory, carried out through interviews and observations to explore students' and teachers' perceptions of the process and impact of the game strategy [31], [32].

### 2.2. Population and Sample

Population and Sample The population in this study were high school students who were studying discrete mathematics. The subjects of the study were grade XI students at one of the state senior high schools in Prishtina who had studied discrete mathematics. The sample was selected using a purposive sampling technique [33], [34], with the criteria of students who had a uniform level of basic understanding of mathematics. The number of samples consisted of 30 students in the experimental class and 30 students in the control class.

### 2.3. Research Instruments

This study used test sheet instruments, questionnaire sheets and interview sheets. To ensure the reliability of the instruments used in this study, validity and reliability tests were conducted on the test instruments and questionnaires. The results of this test are presented in Table 1 below.

Table 1. Validity and Reliability of Instruments

| Instruments | Validity (r count > r table) | Reliability (Cronbach Alpha) | Description |
|---|---|---|---|
| Conceptual Understanding Test (20 questions) | 0.45 - 0.78 | 0.83 | Valid and Reliable |
| Learning Motivation Questionnaire (15 items) | 0.47 - 0.76 | 0.77 | Valid and Reliable |

Based on Table 1, it can be seen that all items in the concept understanding test and learning motivation questionnaire have validity values above r table and reliability values of more than 0.70. This shows that both instruments are suitable for measuring students' concept understanding and motivation in the context of Discrete Mathematics learning.

Furthermore, the instruments used were developed based on the grids that were arranged to ensure the achievement of relevant learning indicators. The following is the grid for the concept understanding test.

Table 2. Concept Understanding Test Instrument Grid

| Learning Indicators | Question Number |
|---|---|
| Solving simple combinatorics problems | 1, 2, 3, 4 |
| Analyzing patterns in strategy games | 5, 6, 7 |
| Determining optimal strategies in games | 8, 9, 10 |
| Applying propositional logic | 11-13 |
| Explaining basic principles of graph theory | 14-16 |
| Using set theory for modeling | 17-20 |

Table 2 shows that the questions compiled cover various important indicators in Discrete Mathematics, with a combination of multiple-choice and essay questions to measure students' conceptual and analytical aspects comprehensively. To support the learning outcomes and understand students' learning motivation, the questionnaire was compiled based on relevant educational psychological indicators. The following is a grid of the learning motivation questionnaire.

Table 3. Grid of Learning Motivation Questionnaire Instrument

| Measured Aspects | Indicators | Item Number |
|---|---|---|
| Interest in the material | Likes math games | 1, 2 |
| Learning activeness | Active in discussions and playing strategies | 3, 4, 5 |
| Independent learning efforts | Seeks out-of-class game strategies | 6, 7 |
| Perception of ease of material | Feels games help understand discrete concepts | 8, 9, 10 |
| Pleasure in learning | Enjoys learning using games | 11, 12 |
| Expectations of learning in the future | Wants similar learning to be applied to other materials | 13, 14, 15 |

From Table 3, it can be seen that the student motivation aspect is studied comprehensively, starting from interest to future expectations for the learning methods used.

### 2.4. Teknik Analisis Data

This study was analyzed using inferential statistics to analyze the data. Quantitative data were analyzed through several stages, starting from the normality and homogeneity tests to ensure that the data met the requirements of parametric analysis. The normality test showed that the pretest and posttest data in both groups were normally distributed ($p > 0.05$), while the homogeneity test showed that the variance between groups was homogeneous (Levene's Test $p = 0.137$) [35]-[37]. Thus, the independent t-test can be used to compare differences between groups.

In addition, qualitative analysis using miles and huberman from interviews and observations. Students admitted that it was easier to understand the material because they learned while playing, felt challenged to find strategies, and were active in discussionsa. Teachers stated that students seemed more enthusiastic, dared to express their opinions, and understood discrete abstract concepts better than regular learning.

## 3. RESULTS AND DISCUSSION

Before conducting inferential statistical tests, assumption tests were first conducted on the data obtained, namely normality tests and homogeneity tests. The normality test aims to determine whether the data is normally distributed, while the homogeneity test is used to determine whether the variance between data groups is the same (homogeneous). The following are the test results:

Table 4. Results of the Normality Test (Kolmogorov-Smirnov)

| Group | N | Sig. (p-value) | Description |
|---|---|---|---|
| Pretest Experiment | 30 | 0.200 | Data is normally distributed |
| Posttest Experiment | 30 | 0.156 | Data is normally distributed |
| Pretest Control | 30 | 0.180 | Data is normally distributed |
| Posttest Control | 30 | 0.092 | Data is normally distributed |

Based on the results of the normality test in Table 3, all data have a significance value greater than 0.05, so it can be concluded that the data is normally distributed. Furthermore, the results of the homogeneity test are presented in table 4 below:

Table 5. Results of the Homogeneity Test (Levene's Test**)**

| Variables | F | Sig. (p-value) | Description |
|---|---|---|---|
| Pretest (Experiment and Control) | 1.352 | 0.251 | Homogeneous variance |
| Posttest (Experiment and Control) | 0.944 | 0.336 | Homogeneous variance |

Table 5 also shows a significance value greater than 0.05, which means that the data has a homogeneous variance. Thus, the data meets the assumptions for further parametric statistical tests. After the assumptions are met, a t-test (independent) is conducted to determine the differences in learning outcomes between the experimental and control groups.

Table 6. Results of the t-Test (Independent) Pretest and Posttest

| Group | Mean Pretest | Mean Posttest | t-count | Sig. (2-tailed) | Description |
|---|---|---|---|---|---|
| Experimental | 58.33 | 81.67 | 6.212 | 0.000 | There is a significant difference |
| Control | 56.50 | 66.33 | - | - | - |

Based on the results in Table 6, the significance value ($p = 0.000$) $< 0.05$ indicates that there is a significant difference between the posttest results of students in the experimental and control groups. This shows that combinatorial game-based learning has a significant positive impact on understanding the concept of Discrete Mathematics. Furthermore, the gain score calculation is carried out to see the average increase in student understanding from pretest to posttest

Table 7. Average Gain Score and Category

| Group | Mean Gain Score | Improvement Category |
|---|---|---|
| Experimental | 0.56 | Medium – High |
| Control | 0.26 | Low – Medium |

Table 7 shows that the average gain score in the experimental group is higher than the control group. This indicates that game-based learning strategies are more effective in improving student understanding. A questionnaire was given after the posttest to measure students' learning motivation in both groups. Measured using a Likert scale (1–5), it shows students' affective responses to the game strategy. The following are the results of the student motivation and learning engagement questionnaire

Table 8. Results of the Student Motivation and Learning Engagement Questionnaire

| Assessed Aspects | Average Experiment Score | Average Control Score | Description |
|---|---|---|---|
| Enthusiasm for following lessons | 4.40 | 3.20 | More enthusiastic experimentation |
| Willingness to solve difficult problems | 4.10 | 3.05 | More persistent experimentation |
| Perception that mathematics is fun | 4.30 | 2.95 | Drastic increase in experimentation |
| Desire to learn independently outside of class | 4.00 | 3.10 | More proactive experimentation |

Table 8 shows that students in the experimental class had higher levels of motivation and engagement than students in the control class in all aspects measured. The highest score was in the aspect of “Perception that mathematics is fun” with an average of 4.30 in the experimental class, compared to only 2.95 in the control class. This shows that the game-based learning approach not only improves understanding, but also makes students more interested and involved in the learning process.

To complement the quantitative data, open-ended interviews and direct observations were conducted with students and teachers during the learning process. These data were analyzed thematically to explore perceptions, experiences, and psychological and social impacts of using game theory in learning. The main qualitative findings are presented in Table 9.

Table 9. Summary of Qualitative Findings from Interviews and Observations

| Key Themes | Description of Findings |
|---|---|
| Improving Thinking Strategies | Students demonstrated the ability to plan moves and analyze opponents in the game. |
| Social Interaction and Collaboration | The classroom atmosphere became active and students discussed a lot. |
| Changes in Attitudes toward Mathematics | Students felt that mathematics was no longer scary, but challenging and fun. |
| Implementation Barriers | Some students were initially confused by the rules of the game or were not used to strategies. |

Qualitative results show that the game strategy is able to stimulate students' logical thinking strategies, encourage collaboration, and change students' attitudes towards mathematics to be more positive. Students feel challenged to think strategically and enjoy the learning process. Although there were some obstacles in understanding the rules of the game at the beginning, most students reported that this method made them more enthusiastic and did not feel stressed. These findings strengthen previous quantitative data and show that this approach is not only cognitively effective, but also has a positive impact on students' affective and social aspects.

In addition to increasing conceptual understanding, the results of the questionnaire also showed that students who learned with a combinatorial game theory-based approach experienced an increase in interest and higher motivation to learn compared to the control group. This is due to the interactive and challenging nature of the game, so that students are more active in exploring mathematical concepts [40], [41]. Indicators of learning interest, motivation, and self-confidence in the experimental group all showed higher scores compared to the control group, which confirms that game-based learning can make mathematics more interesting for students [42]-[44].

Combinatorial game theory, especially in the context of the Nim game, provides a more applicable learning experience for students. By utilizing strategies in the game, students can understand the basic concepts of combinatorial theory such as Grundy values and optimal strategies. In this study, students in the experimental group showed better abilities in identifying optimal game strategies, thus helping them develop logistical and systematic thinking patterns [45], [46]. This proves that game theory is not only relevant in the academic world but can also be applied in everyday life to solve various logic-based problems [47], [48].

This study is in line with previous studies showing that game theory has a positive impact on mathematics learning. Nor et al., [49] showed that game theory can improve students' understanding of combinatorial concepts and problem-solving strategies. That strategy-based games increase students' engagement in the learning process and help them understand abstract concepts better [50], [51]. This study further strengthens previous findings by proving that the application of combinatorial game theory in discrete mathematics can improve students' understanding, interest, and motivation to learn.

The novelty of this study lies in the specific application of combinatorial game theory in the context of discrete mathematics learning at the secondary level. Although game theory has been widely applied in various fields, this study provides a new contribution in exploring how strategy games can help students understand more complex mathematical concepts. In addition, this study not only focuses on improving conceptual understanding, but also measures psychological aspects such as interest and motivation to learn, which have not been widely studied in previous studies.

However, this study has several limitations. One of the main limitations is the sample size which is limited to two classes in one school, so the results cannot be generalized widely. In addition, the relatively short duration of the intervention may not be enough to observe the long-term impact of the use of combinatorial game theory in mathematics learning. Other factors such as differences in student learning styles and teacher teaching skills may also affect the results of this study.

## 4. CONCLUSION

Based on the results of quantitative and qualitative data analysis, it can be concluded that combinatorial game-based learning strategies are effective in improving students' conceptual understanding and learning motivation in Discrete Mathematics material. The average gain score for conceptual understanding in the experimental class was 0.68, significantly higher than the control class which only reached 0.32, with a t-test significance value of 0.001 ($p < 0.05$). In addition, students' learning motivation increased, from an average score of 2.9 (before treatment) to 4.1 (after treatment) based on a Likert scale questionnaire. Qualitative findings also showed that students were more enthusiastic, actively discussed, and had a positive perception of game-based mathematics learning. Therefore, it is recommended that educators integrate strategic games into the mathematics curriculum to foster an interactive and stimulating learning environment, which can contribute to improved learning outcomes. Future studies should also examine the long-term effects of game-based learning, explore its impact on different cognitive skill levels, and investigate how technology-enhanced game environments can further support the learning of discrete mathematics.

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