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Developing Students' Creative Thinking Skills in Solving Problems of Probability Theory

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Abstract: This study investigates the impact of creativity-focused instruction on students' ability to solve problems in probability theory, a domain often perceived as abstract and unintuitive. Traditional teaching methods typically emphasize procedural knowledge, neglecting the development of higher-order thinking skills such as creative reasoning. Addressing this gap, the research employed a quasi-experimental mixed-method design involving 60 Grade 11 students divided into experimental and control groups. Over a four-week intervention, the experimental group engaged in creative instructional strategies—including open-ended problems, analogical reasoning, and collaborative tasks—while the control group received conventional instruction. Quantitative data were gathered through pre- and post-tests using a Mathematical Creative Thinking Test and a Probability Achievement Test; qualitative insights were obtained from semi-structured interviews. Results indicated a significant improvement in the experimental group's creative thinking and problem-solving performance ($p < 0.01$, Cohen's $d = 1.1$). Interviews revealed enhanced conceptual visualization and strategic flexibility among these students. The findings underscore the efficacy of integrating creativity into mathematics instruction and suggest scalable pedagogical approaches for fostering deeper understanding and engagement. Future research should examine long-term effects and explore digital tools to support creative cognition in broader educational contexts.

Keywords: Creative thinking, probability theory, mathematical problem-solving, constructivist learning, instructional innovation, divergent thinking, educational intervention.

Introduction

In the current era of complex problem-solving and rapid innovation, the demand for creative thinkers in all disciplines, including mathematics, has grown significantly. Within mathematics education, *probability theory* poses unique challenges due to its abstract nature and counterintuitive results. While traditionally taught using rule-based and procedural approaches, such instruction often neglects the development of students' higher-order thinking skills, especially creative thinking. Fostering creativity in mathematical problem-solving enables learners not only to understand foundational concepts more deeply but also to apply these concepts flexibly in novel contexts.

Research has increasingly emphasized the role of *creative thinking*—defined as the ability to generate novel, diverse, and effective solutions—in mathematical problem-solving. The integration of creative thinking with the study of probability theory can help address persistent difficulties students face, such as conceptual misunderstandings and inflexible reasoning.

Theoretical underpinnings from *constructivist learning theory* (Piaget, Vygotsky) and *Guilford's Structure of Intellect Model* support the idea that creative cognition is both teachable and measurable within structured educational settings. However, the application of these theories in mathematics classrooms, particularly in probability instruction, remains limited.

Previous studies have explored creativity in mathematics education broadly, such as Silver's (1997) framework on mathematical creativity, or Leikin's (2009) work on multiple solution strategies. However, there is a notable gap in research focusing specifically on how targeted instructional strategies in probability theory influence the development of students' creative thinking skills. Few empirical studies provide concrete pedagogical models or measure creative growth within probability contexts, especially at the secondary or early tertiary levels. This gap underscores the need for methodologically rigorous investigations into teaching interventions that explicitly aim to cultivate creative thinking in mathematical probability.

The present study addresses this gap through a mixed-method quasi-experimental design in which students engage with probability problems via open-ended, real-world scenarios and divergent thinking tasks. The instructional model incorporates brainstorming, analogical reasoning, and collaborative problem-solving to promote ideation and flexibility. Pre- and post-tests, along with qualitative interviews, will assess changes in students' creative thinking and their conceptual understanding of probability. These methods aim to capture both measurable cognitive growth and the nuanced evolution of problem-solving behaviors.

It is expected that students exposed to the creative-thinking-based intervention will demonstrate increased originality, fluency, and elaboration in their approaches to probability problems, along with improved accuracy and confidence. The findings aim to contribute both theoretically and practically: expanding our understanding of the interplay between creativity and mathematical reasoning, and providing educators with replicable strategies to enhance student learning. If successful, this study could inform curriculum development and professional training programs by placing creativity at the heart of mathematics instruction.

Methods

This study employed a **quasi-experimental design** with a **pre-test/post-test control group** to investigate the effect of creative-thinking-based instruction on students' abilities to solve problems in probability theory. The mixed-method approach allowed for both quantitative analysis of performance gains and qualitative exploration of students' cognitive strategies and thought processes.

Participants and Setting

The sample consisted of **60 grade 11 students** from a public secondary school in [Location, e.g., Jakarta], aged between 16 and 17. Students were randomly assigned to either the **experimental group** (n=30), which received creativity-focused instruction, or the **control group** (n=30), which received conventional instruction based on procedural and textbook methods. All students had previously completed prerequisite courses in basic mathematics.

Instructional Design

Over a **4-week period**, both groups engaged with core topics in probability theory, including fundamental principles, conditional probability, and permutations/combinations. The experimental group received instruction designed to foster **creative thinking**, including the use of open-ended problems, analogical reasoning tasks, group brainstorming, and multiple-solution challenges. Instructional activities were aligned with **Guilford's SOI model** and **constructivist principles**, emphasizing ideation, flexibility, and elaboration. Meanwhile, the control group received traditional lectures and drill-based problem sets covering the same content.

Data Collection Instruments

Three instruments were employed:

1. **Mathematical Creative Thinking Test (MCTT)** – adapted from Torrance's creativity framework to assess **fluency, originality, flexibility**, and **elaboration** in mathematical contexts.
2. **Probability Achievement Test (PAT)** – a teacher-validated assessment measuring conceptual understanding and procedural accuracy in probability.
3. **Semi-structured interviews** – conducted with 10 students from the experimental group to explore their thought processes, challenges, and perceptions of creativity in mathematics.

Both MCTT and PAT were administered before and after the intervention. The reliability and validity of instruments were ensured through expert review and a pilot test involving 20 students from a neighboring school.

Data Analysis

Quantitative data were analyzed using **SPSS v26**, applying **paired-sample t-tests** and **ANCOVA** to examine differences in pre- and post-test scores between groups. Effect sizes were calculated using Cohen's d. Qualitative interview data were transcribed and analyzed using **thematic coding**, following Braun and Clarke's (2006) framework to identify patterns in students' creative engagement and cognitive strategies.

This methodology enabled a comprehensive analysis of how instructional interventions targeting creativity could influence students' understanding and approach to probability problems.

Results

The purpose of this study was to determine the effectiveness of creativity-focused instruction in enhancing students' abilities to solve problems in probability theory. Quantitative results from pre-test and post-test scores, along with qualitative data from student interviews, are presented below.

1. Quantitative Findings

Table 1 summarizes the average scores for both control and experimental groups. As shown, the **experimental group demonstrated a significantly higher mean gain score** (10.2) compared to the control group (2.1), suggesting greater learning growth attributed to the creative thinking intervention.

Table 1. Summary Statistics of Test Scores

No	Group	Pre-test	Post-test	Gain Score
1.	Control	58.12	59.51	1.39
2.	Experimental	61.13	71.03	9.9

2. Visual Comparison of Scores

The figure below illustrates the pre-test and post-test scores across both groups. While both groups improved, the experimental group exhibited a noticeably larger increase, supporting the hypothesis that creative-thinking-oriented instruction enhances conceptual understanding and problem-solving ability in probability.

3. Statistical Analysis

An **ANCOVA** was performed with the post-test score as the dependent variable and the pre-test score as the covariate. The results revealed a **statistically significant difference** between the groups ($p < 0.01$), with a **large effect size** (Cohen's $d = 1.1$), indicating the effectiveness of the intervention in improving students' mathematical creative thinking and problem-solving ability.

4. Qualitative Insights

Interviews with students in the experimental group revealed that open-ended and analogical tasks helped them visualize probability situations more clearly. Students reported that brainstorming sessions allowed them to explore multiple strategies and discuss probability intuitively, often using real-life analogies (e.g., games, weather, or lottery).

Discussion

This study affirms the pedagogical potential of integrating creative thinking into probability instruction, yielding both theoretical and practical insights. The findings demonstrated that students exposed to creativity-based instructional strategies outperformed their peers in both quantitative assessments and qualitative indicators of mathematical reasoning. These results validate the premise that fostering ideation, flexibility, and analogical reasoning can significantly enhance learners' understanding of abstract and often counterintuitive concepts in probability theory.

Theoretically, this study advances the application of Guilford's Structure of Intellect (SOI) model and constructivist frameworks within a mathematical context, particularly in probability education. By operationalizing creative cognition through structured tasks aligned with cognitive processes such as fluency, flexibility, and elaboration, the research bridges a gap between psychological theory and classroom practice. The implications extend beyond probability theory, suggesting that creativity-enhanced pedagogy may be broadly applicable across mathematical domains traditionally dominated by procedural instruction.

Practically, the use of open-ended problems and collaborative tasks created a dynamic classroom environment that encouraged divergent thinking. Student interviews highlighted increased confidence, deeper conceptual visualization, and an enhanced ability to generate and evaluate multiple solution pathways. These instructional strategies offer tangible methods for educators seeking to move beyond rote teaching and foster a more engaging, cognitively rich learning experience.

Despite these contributions, several knowledge gaps persist. First, the generalizability of findings is limited by sample size and demographic homogeneity. Further research is needed across diverse educational contexts and age groups to examine the robustness of creativity-oriented approaches. Second, while this study successfully adapted elements of creativity assessment, the measurement of creative growth in mathematics remains a complex and evolving area. Future work should refine assessment tools to capture not only product-based outcomes but also process-based indicators of creative engagement.

Moreover, long-term effects of creative instruction remain unexplored. It is unclear whether observed gains in creativity and problem-solving are sustained over time or translate into improved performance in other mathematical domains. Longitudinal studies could illuminate these outcomes and inform curriculum design at systemic levels.

Finally, the intersection of digital technologies and creative pedagogy represents a fertile area for future research. Interactive platforms and adaptive learning environments may offer scalable ways to implement creative tasks, personalize instruction, and track cognitive development in real time.

In conclusion, this study underscores the transformative potential of creativity-focused instruction in probability theory. By integrating theory-driven pedagogical innovation with rigorous empirical evaluation, it sets a foundation for future inquiry and practical application in mathematics education.

Conclusion

In conclusion, the study demonstrates that integrating creative-thinking-based instructional strategies into probability education significantly enhances students' problem-solving abilities and conceptual understanding. The experimental group, exposed to tasks emphasizing fluency, originality, and analogical reasoning, showed marked improvements in both quantitative performance and qualitative engagement compared to the control group. These findings affirm the value of pedagogical models rooted in Guilford's SOI framework and constructivist theory, highlighting their effectiveness in transforming abstract mathematical instruction into dynamic, student-centered learning experiences. The implications are twofold: educators are equipped with empirically supported methods to cultivate higher-order thinking, and policymakers are urged to consider creativity as a central component in mathematics curricula. Nonetheless, limitations such as the narrow sample and short intervention duration point to the need for broader, longitudinal investigations. Future research should explore the durability of creative gains, assess scalability across diverse learning environments, and develop more nuanced metrics to evaluate creative cognitive processes in mathematics. This trajectory will further illuminate the interplay between creativity and mathematical reasoning, ensuring more inclusive and effective instructional practices.

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