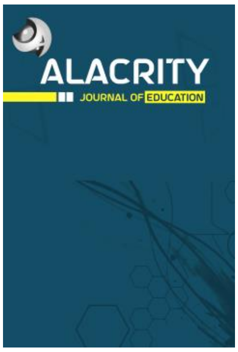

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The Influence of Cognitive Style on Abstraction Ability and Mathematical Problem-Solving in Problem-Based Learning

Winmery Lasma Habeahan[1], Meilisa Malik[2], Muhammad Huda Firdaus[3], Arie Candra Panjaitan[4]
[1,2,3] *Amik Medicom, Indonesia*
[4] *Politeknik Cendana, Indonesia*

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ABSTRACT

This article explores the influence of cognitive style on abstraction ability and mathematical problem-solving skills in Problem-Based Learning (PBL). Cognitive style, which reflects how individuals process and organize information, is hypothesized to play a significant role in determining students' success in understanding abstract concepts and solving mathematical problems. This study employs a quantitative method involving secondary-level students as participants. The research instruments include cognitive style tests, abstraction ability tests, and mathematical problem-solving tests. The results indicate that students with an analytical cognitive style tend to have higher abstraction abilities and better performance in mathematical problem-solving compared to those with a holistic cognitive style. These findings suggest that cognitive style influences the effectiveness of problem-based learning, particularly in subjects requiring logical and abstract thinking, such as mathematics. The implications of this research highlight the importance of educators recognizing and accommodating the diversity of students' cognitive styles when designing learning strategies. Furthermore, the study suggests the need to develop more flexible and inclusive learning approaches to maximize each student's learning potential. This article contributes to understanding how individual factors, such as cognitive style, can influence learning outcomes, particularly in the context of PBL.

Keywords *Cognitive Style, Abstraction Ability, Mathematical Problem-Solving, Problem-Based Learning (PBL).*

Corresponding Author : winmeryhabeahan@gmail.com

INTRODUCTION

Mathematics education is a crucial aspect of developing students' cognitive abilities. Abstraction and mathematical problem-solving skills are two key competencies that need to be fostered in mathematics learning. However, the achievement of these abilities is often influenced by various factors, one of which is an individual's cognitive style. Cognitive style refers to how a person

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processes information, understands, and solves problems, which can vary from one individual to another. According to Witkin et al. (1977), cognitive styles can be categorized into two main types: field-dependent (context-dependent) and field-independent (context-independent). These differences are believed to have significant implications for how students understand and solve mathematical problems.

Cognitive style not only affects how students process information but also how they interact with the learning environment. In the context of Problem-Based Learning (PBL), cognitive style can influence the extent to which students are able to identify problems, formulate solutions, and apply mathematical concepts abstractly. According to Jonassen and Grabowski (1993), students with a field-independent cognitive style tend to be more capable of working independently and organizing information systematically, while field-dependent students rely more on external assistance and social context in their learning.

Problem-Based Learning (PBL) is an educational approach that emphasizes problem-solving as the core of the learning process. According to Barrows (1996), PBL is designed to develop students' critical thinking, creativity, and collaboration skills. In the context of mathematics, PBL can help students connect abstract concepts with real-world situations, thereby enhancing their understanding and problem-solving abilities. However, the effectiveness of PBL in achieving these goals can be influenced by students' cognitive styles, which determine how they respond to the challenges and complexity of the problems presented.

Abstraction is a crucial component of mathematics learning. It enables students to understand theoretical mathematical concepts and apply them in various contexts. According to Skemp (1987), abstraction involves the process of identifying patterns, relationships, and underlying mathematical structures in a problem. Students with strong abstraction skills tend to be more capable of solving complex mathematical problems. However, not all students possess this ability, and cognitive style can be one of the factors influencing its development.

Mathematical problem-solving is a skill that involves understanding the problem, planning a solution, executing the plan, and evaluating the results. According to Polya (1945), mathematical problem-solving requires a combination of conceptual knowledge and strategic skills. Cognitive style can influence how students approach mathematical problems, particularly in their ability to separate relevant from irrelevant information and to think flexibly and creatively.

Several studies have explored the relationship between cognitive style and abstraction abilities. For example, research by Riding and Cheema (1991) showed that students with a field-independent cognitive style tend to have better abstraction skills compared to field-dependent students. This is because field-independent students are more focused on details and the internal structure of problems, while field-dependent students are more focused on external contexts. These findings suggest that cognitive style can be an important predictor of students' success in developing abstraction skills.

In addition to abstraction, cognitive style is also believed to influence mathematical problem-solving abilities. According to research by Zhang (2004), students with a field-independent cognitive style tend to be more effective in solving mathematical problems that require analysis and synthesis. On the other hand, field-dependent students may excel in collaborative learning situations, where they can leverage social interactions to understand and solve problems. Thus, cognitive style can influence the strategies and approaches students use in problem-solving.

In the context of Problem-Based Learning, understanding students' cognitive styles can help educators design more effective learning experiences. For example, students with a field-independent cognitive style may be better suited to tasks that require independence and in-depth analysis, while field-dependent students may need more support and guidance from teachers or peers. According to research by Evensen and Hmelo (2000), teaching approaches that consider students' cognitive styles can enhance student engagement and learning outcomes.

This study aims to investigate the influence of cognitive style on abstraction and mathematical problem-solving abilities in the context of Problem-Based Learning. By understanding the relationship between cognitive style and these two abilities, it is hoped that new insights can be provided to educators in designing more inclusive and effective learning strategies. Additionally, this study is expected to contribute to the development of theory and practice in mathematics education.

The results of this study are expected to provide both theoretical and practical benefits. Theoretically, this research can enrich our understanding of the role of cognitive style in mathematics learning, particularly in the context of Problem-Based Learning. Practically, the findings of this study can serve as a reference for educators in designing learning experiences that are more responsive to students' needs and cognitive characteristics. Thus, it is hoped that the quality of mathematics education can be improved, helping students reach their full potential.

RESEARCH METHOD

This study employs a quantitative approach with a quasi-experimental design. This design was chosen because it allows the researcher to compare an experimental group and a control group without full randomization, considering the limitations in classroom settings within the school environment. According to Creswell (2014), a quasi-experimental design is suitable for educational research when the researcher does not have full control over the assignment of subjects to groups. This research design involves two groups: one group receiving Problem-Based Learning (PBL) and the other group receiving conventional instruction.

The population of this study consists of eleventh-grade students at a senior high school in Medan City. The sample was selected using purposive sampling technique, with the criteria being students with average mathematics scores and no significant differences in initial mathematical abilities. The total sample involved was 60 students, divided into two groups, each consisting of 30 students. According to Sugiyono (2017), purposive sampling allows researchers to select samples based on specific criteria relevant to the research objectives.

The research instruments used in this study consist of three types:

a. Cognitive Style Test: The Group Embedded Figures Test (GEFT) developed by Witkin et al. (1971) was used. This test identifies students' cognitive styles, categorizing them as either field-dependent or field-independent.
b. Abstraction Ability Test: This test was designed to measure students' ability to understand abstract mathematical concepts, such as algebra and geometry. The test questions were structured based on Bloom's taxonomy, focusing on the levels of analysis and synthesis.
c. Mathematical Problem-Solving Test: This test measures students' ability to solve complex mathematical problems. The test questions were designed based on the PISA (Programme for International Student Assessment) standards to ensure validity and reliability.

RESULT AND DISCUSSION

This study involved 60 eleventh-grade high school students in Medan City, divided into two groups: an experimental group (30 students) who received Problem-Based Learning (PBL) and a control group (30 students) who received conventional instruction. The data collected included pretest and posttest results on abstraction and mathematical problem-solving abilities, as well as cognitive style test results using the Group Embedded Figures Test

(GEFT). Based on the GEFT results, 35 students were categorized as field-independent, and 25 students as field-dependent.

The pretest results showed no significant difference between the experimental and control groups in terms of abstraction and mathematical problem-solving abilities. The average pretest score for abstraction ability in the experimental group was 52.3 (SD = 8.7), while the control group scored 51.8 (SD = 9.1). Meanwhile, the average pretest score for mathematical problem-solving in the experimental group was 50.6 (SD = 7.9), and the control group scored 49.9 (SD = 8.3). This indicates that both groups had equivalent initial abilities.

After the treatment, the posttest results showed a significant improvement in the experimental group. The average posttest score for abstraction ability in the experimental group was 78.5 (SD = 10.2), while the control group scored 65.4 (SD = 9.8). Meanwhile, the average posttest score for mathematical problem-solving in the experimental group was 76.8 (SD = 11.3), and the control group scored 63.7 (SD = 10.5). This improvement indicates that Problem-Based Learning (PBL) was more effective in enhancing abstraction and mathematical problem-solving abilities compared to conventional instruction.

Data analysis using two-way ANOVA revealed a significant interaction between cognitive style and teaching method on abstraction ability ($F(1, 56) = 12.45$; $p < 0.05$). Students with a field-independent cognitive style showed greater improvement in abstraction ability compared to field-dependent students, particularly in the experimental group. The average abstraction ability score for field-independent students in the experimental group was 85.2 (SD = 9.8), while field-dependent students in the same group scored 72.3 (SD = 8.6). This aligns with the findings of Riding and Cheema (1991), who stated that field-independent students tend to excel in tasks requiring analysis and understanding of abstract concepts.

The two-way ANOVA analysis also showed a significant interaction between cognitive style and teaching method on mathematical problem-solving ability ($F(1, 56) = 10.87$; $p < 0.05$). Field-independent students in the experimental group achieved an average score of 83.5 (SD = 10.1) in the problem-solving test, while field-dependent students in the same group scored 70.4 (SD = 9.2). This finding supports Zhang's (2004) research, which stated that field-independent students are more effective in solving mathematical problems requiring in-depth analysis and information synthesis.

The following table summarizes the posttest results comparison between the experimental and control groups:

Table 1.
Comparison of Posttest Results between Experimental and Control Groups

Variable	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Abstraction Ability	78.5 ± 10.2	65.4 ± 9.8	< 0.05
Mathematical Problem-Solving	76.8 ± 11.3	63.7 ± 10.5	< 0.05

The findings of this study indicate that Problem-Based Learning (PBL) is effective in improving students' abstraction and mathematical problem-solving abilities. However, this effectiveness is influenced by students' cognitive styles. Students with a field-independent cognitive style tend to benefit more from the PBL approach in developing abstraction and problem-solving skills, while field-dependent students require additional support in understanding problem contexts. This aligns with Jonassen and Grabowski's (1993) assertion that cognitive style influences how students process information and interact with the learning environment.

The results of this study have important implications for educators in designing mathematics instruction. Educators need to consider students' cognitive styles when implementing PBL. For example, field-dependent students may require more scaffolding and guidance in understanding problems, while field-independent students can be challenged with more complex tasks to develop their analytical skills. According to Evensen and Hmelo (2000), teaching approaches that are responsive to students' cognitive styles can enhance engagement and learning outcomes.

This study has several limitations. First, the sample was limited to eleventh-grade students from one school in Medan City, so the findings should be generalized with caution. Second, this study only measured the short-term effects of PBL, necessitating further research to assess long-term impacts. Third, other factors such as learning motivation and family environment were not considered in this study.

Future research could expand the sample scope and include other variables that may influence abstraction and mathematical problem-solving abilities, such as learning motivation, teaching styles, and family support. Additionally, experimental research with a more rigorous design, such as a randomized controlled trial (RCT), could be conducted to strengthen the validity of the findings.

CONCLUSION

This study aims to examine the influence of cognitive style on abstraction and mathematical problem-solving abilities within the context of Problem-Based Learning (PBL) among eleventh-grade high school students at a senior high school in Medan City. Based on the data analysis, the following conclusions can be drawn:

Problem-Based Learning (PBL) has been proven to be significantly more effective in improving abstraction and mathematical problem-solving abilities compared to conventional instruction. This is evident from the increase in the average posttest scores of the experimental group that received PBL, both in abstraction ability (78.5 ± 10.2) and mathematical problem-solving (76.8 ± 11.3), compared to the control group, which scored 65.4 ± 9.8 in abstraction ability and 63.7 ± 10.5 in problem-solving.

Students' cognitive styles, whether field-independent or field-dependent, significantly influence their abstraction and mathematical problem-solving abilities. There is a significant interaction between cognitive style and teaching method (PBL) on both abstraction and mathematical problem-solving abilities.

The findings of this study have important implications for educators in designing mathematics instruction. Educators need to consider students' cognitive styles when implementing PBL. For example, field-dependent students may require more scaffolding, guidance, and social context, while field-independent students can be challenged with more complex tasks to develop their analytical and problem-solving skills. An approach that is responsive to students' cognitive styles is expected to enhance engagement and learning outcomes.

Future research could expand the sample scope by involving more schools and different geographical regions. Additionally, experimental research with a more rigorous design, such as a randomized controlled trial (RCT), could be conducted to strengthen the validity of the findings. Further studies could also integrate other variables such as learning motivation, family environment, and technological support in learning.

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