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METACOGNITIVE SKILLS OF COLLEGE STUDENTS IN MATHEMATICS PROBLEM SOLVING: OVERVIEW BY STUDENT'S FIELD DEPENDENT

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ABSTRACT

Overall, this study aims to assess college students' field-dependent metacognitive skills in mathematics problem-solving. We administered the Group Embedded Figures and Mathematical Ability Tests to 35 future educators from a private school in Sukoharjo, Indonesia. Students' questioning of each group served to gauge their proficiency in solving problems, as shown in the results. Participants also demonstrated partially achieved metacognitive abilities, as measured by the (metacognitive) skills criterion, which encompassed tasks such as planning, monitoring, assessing, and predicting. First, the participants documented and explained the facts given in the question. Second, they checked the results against the plan. Third, they evaluated the success of the objectives by analyzing the results to make sure everything went according to plan. Finally, they predicted and stated the results of the problem-solving process. In light of these findings, researchers and teachers facing comparable obstacles would do well to delve deeper into the function of metacognitive abilities in problem-solving.

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1. INTRODUCTION

According to Gurat & Medula (2016) and Jagals & Walt (2016), metacognition plays a significant role in problem-solving activities and has a strong connection to the process of learning mathematics. Researchers have conducted numerous experiments in the field of mathematics education in recent years (Jäder et al., 2020). People widely recognize the significance of problem-solving in mathematics, especially during the learning phase where students gain expertise by applying their knowledge and skills to solve non-routine problems (Abdullah et al., 2017; Son et al., 2020). Despite its numerous requirements, mathematics has recognized this condition as a significant domain. Furthermore, learners exhibit metacognitive abilities, which are known to effectively address current challenges. The connection between metacognitive skills and problem-solving is strong, as they involve advanced thinking abilities that actively regulate cognitive processes during the learning process (Antonietti et al., 2000; Ozsoy & Ataman, 2009; Susanto et al., 2020). Clarke et al. (2007) recognize this skill as the primary factor in resolving mathematical problems that impact pupils' rates of success in arithmetic. Researchers have found that learners with metacognitive skills enhance cognitive regulation, particularly in declarative, conditional, and procedural knowledge, when addressing issues. Nevertheless, learners have a deficiency in metacognitive skills, which consequently hinders their ability to effectively solve problems.

Pre-service instructors must have metacognitive skills to effectively solve mathematics problems during the learning process. Primarily, incorporating metacognitive skills into different learning tasks is anticipated to yield advantageous enhancements to the quality of the learning being conducted (Hargrove & Nietfeld, 2015; Smith & Mancy, 2018). Hence, metacognitive skills play a crucial role in the learning process by enhancing the educational activities and outcomes of college students', ultimately influencing their problem-solving abilities. Additionally, metacognitive skills are a component of unidimensional knowledge that is notably necessary for future academic pursuits.

Metacognitive skills encompass task orientation, planning, monitoring, evaluation, and recapitulation. According to Veenman & Cleef (2019), metacognitive skills are manifested as a set of internalized self-instructions that guide pupils on what actions to take as well as when, why, and how to complete tasks. Metacognitive skills govern cognitive processes, encompassing activities such as planning, monitoring, evaluation, and prediction (Desoete, 2009b; Veenman, Van Hout-Wolters, & Afflerbach, 2006). The majority of studies are stated to utilize only three levels of metacognitive skills, with only a limited number of studies examining the four processes. Hence, it is intriguing to execute these four procedures in order to enhance the acquisition of metacognitive abilities. These procedures encompass the activities of devising a strategy, closely observing progress, assessing outcomes, and utilizing foresight.

Researchers like Pennequin et al. (2010) claim that the outcomes of training in metacognitive skills form the basis of a number of problem-solving studies. The findings demonstrated that metacognitive training helped both average and low performers advance and solve mathematics difficulties. But according to Jagals & Walt's (2016) findings, metacognitive skills are necessary for addressing mathematical difficulties because of their capacity to promote awareness, particularly through preparation and observation. Van der Stel et al. (2010) further demonstrated the independence of metacognitive skills from intellectual aptitude in their contribution to learning performance. Generally, we recognize the generic nature of the emergence of metacognitive abilities. The ability to use domain-specific metacognitive skills is crucial for addressing problems.

Because they enable future educators to regulate their own thought processes, the descriptions provided here highlight the significance of metacognitive abilities in problem solving. In addition, research by Abdullah et al. (2017) demonstrated that students performed poorly when asked to solve mathematical tasks that were not routine.

When it came to tackling non-routine mathematical tasks, pupils' metacognitive abilities varied significantly across performance levels. Several previously cited accounts recommend prioritizing metacognitive abilities in this process. Improving students' capacity for metacognition also has far-reaching implications for education at all levels, from college students' to entire communities. There was a correlation between metacognitive abilities and mathematical achievement, according to Tachie and Molepo's (2019) findings. Additionally, researchers have noted that teachers unknowingly use metacognitive skills to help pupils resolve classroom issues. This description further made research on metacognitive abilities possible.

This study finds a connection between the technique and metacognitive skill stages. When establishing a connection between problem-solving and metacognitive abilities, Lioe et al. (2006) frequently employed these approaches. This led to the organization of problem-solving steps and the progression of metacognitive skills (Lioe et al., 2006; Santos-Trigo, 2020; Desoete, 2009b). Finally, the researchers assembled and modified a set of metacognitive skills related to problem-solving for use with college students'. Some examples of them are: (1) Ability to plan ahead: This category includes characterizations such as documenting existing knowledge and inquiries, establishing problem-solving goals, formulating a strategy for achieving those goals, and finally, reviewing the process for any completed problems or links. (2) The ability to monitor progress encompasses problem-solving skills, ensuring the accuracy of all procedures, and determining the feasibility of planned implementation processes. (3) Competence in evaluating: This approach is useful for assessing progress toward objectives and solving other types of challenges. (4) The ability to foretell future outcomes, such as the solutions to identified problems, is part of the broader category of prediction skills. However, there is another aspect to consider: the cognitive style.

Cognitive style is one of several indicators of a person's mathematical problem-solving abilities (Son et al., 2020). People vary in their tactics for solving mathematical issues, their level of intelligence, their ability to think creatively, and their ways to acquire, retain, and apply knowledge. According to Volkova and Rusalov (2016), there are many kinds of cognitive styles. These include intuitive and systematic approaches, impulsive and reflective styles, and field-dependent and independent styles. The primary emphasis in this investigation is on the field-dependent and independent techniques' cognitive style, however. A number of scholars throughout the world are keen on investigating the correlation between different aspects of cognitive style and mathematical aptitude (Chrysostomou et al., 2013). Despite the abundance of literature on field-independent and dependent cognitive styles in general, these approaches have received relatively little scrutiny when applied to domains like mathematical operations and problem-solving in particular (Nicolaou & Xistouri, 2011).

Field-independent cognitive styles exhibit greater self-reliance and confidence compared to field-dependent techniques, which rely on external influences (Son et al., 2020; Witkin et al., 1977). These cognitive style distinctions refer to metacognitive talents that aid in solving mathematics tasks, specifically those that require drawing cubes. The results of this study can assist educators in developing more captivating courses on the sections of a cube. Hence, they should unquestionably consider these findings. The primary goal of this study is to examine college students'' metacognitive capabilities in mathematics problem-solving, with a particular focus on cognitive styles.

2. METHOD

This study employed a descriptive-exploratory research approach to comprehensively investigate the metacognitive abilities of college students' in mathematical problem-solving, specifically in relation to "cube slices." The study included a total of thirty-five college students' from a private university located in Sukoharjo, Central Java, Indonesia. This study employed a purposive sample strategy to pick the necessary number of participants (Miles et al., 2018). We directed the participants to complete the Group Embedded Figures and Mathematics Ability Tests, categorizing their solutions into one groups based on their scores. Furthermore, we instructed both participants to solve cube-slice questions to examine the distinct attributes of each group. We then conducted a task-based interview with one pre-service teacher from each group.

Witkin (Witkin et al., 1977) created an instrument that served as the basis for the Group Embedded Figures Test. We divided the content into three sections, each containing a total of nine images. Specifically, there were two introductory examples and seven practice tasks for each category. We utilized observation sheets to document interviews and track the development of metacognitive skills. Prior to its implementation, the instrument underwent rigorous testing for both validity and reliability. To ensure their accuracy and consistency, two mathematicians and one educational specialist examined the question contents and interview sheets. We assessed the instrument's validity based on several factors, including the feasibility of the test questions, the substance, the language used, and the appropriateness of the instructions. We used these criteria to assess the metacognitive abilities of college students'.

To conduct data analysis, the Group Embedded Figures and Mathematics Ability Tests were initially administered. Their results were categorized into two groups based on the GEFT score: field-independent (> 10) and field-dependent (< 10). The GEFT score ranged from 0 to 18. Additionally, the results were also categorized based on the Mathematics Ability Test score (> 80). The research participants consisted of individuals who scored > 80 on the Mathematics Ability Test and had either a field-independent or field-dependent cognitive style. Subsequently, the pre-service instructors were given mathematics challenges and evaluated based on their reasoning abilities while solving the cube slice issue. Every participant underwent meticulous observation, focusing on their metacognitive abilities in problem-solving. Subsequently, the triangulation procedure was conducted to validate the data obtained from the interviews. Triangulation was employed to validate the findings of the students' responses. Furthermore, the pre-service instructor and researcher were assigned the codes S-1 and P, respectively. In conclusion, the findings on the metacognitive abilities of the two college students' in completing mathematical tasks were also summarized.

3. RESULTS AND DISCUSSION

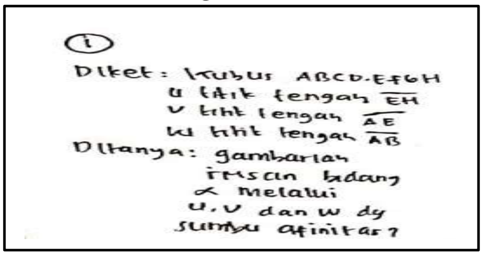
Results

Out of the thirty-five college students' who took the Group Embedded Figures Test, twenty of them scored 10 or higher, while the remaining fifteen scored less than 10. Nevertheless, in the Mathematics Ability Test, eighteen college students' achieved a score of 80 or higher, while the remaining seventeen scored below 80. Upon obtaining the college students'' GEFT and MAT scores, we discovered that ten of them demonstrated a field-independent cognitive style with a score of 80 or higher, while the remaining eight demonstrated a field-dependent cognitive style with a score of 80 or higher. We selected one candidate with field-dependent cognitive styles from the group of eighteen eligible participants who met the criteria. One of the participants' interviews provided insight into the metacognitive skills of college students' in solving mathematical problems. The results of these interviews, in which S-1 stands for field-dependent cognitive styles, are as follows:

Metacognitive Skills Process of S-1

Based on the fact that S-1 had all the details contained in the problem, this meant that the participant understood what was provided and should be discovered in the problem. However, it was observed that S-1 was unable to explain a sketch of knowledge, which was related to the problem. The following showed the written results and interviews of S-1.

Planning Skills of S-1



Translate Version
Given: Cube ABCD.EFGH, U the midpoint of EH, V the midpoint of AE, and W the midpoint of AB
Asked: Draw a slice of the plane through points U, V, and W with the affinity axis?

Figure 1. Answer of S-1

S-1 thought about the methods to understand, by representing and writing them in sentences and symbols. The participant also identified the problem by reading the question instructions first, then understanding it as a whole. S-1 was also reported to have mentioned all the information in the provided questions. In determining problem-solving goals, S-1 ensured that the goals achieved were correct, by reading the instructions about the problem and understanding them, in order to achieve solutions. S-1 also stated that writing things that people have knowledge about, made it easier to understand the meaning of the problem. Based on the completion of plan carried out, the participant's planning solution assured correctness, because the command questions and results were right and clear. Also, S-1 stated that the method used to solve the problem was Geometry. However, S-1 was unable to provide an answer about other knowledge, which was likely to be used in the problem-solving process.

Monitoring Skills of S-1

At the monitoring stage, S-1 was sure that the results of the problem-solving that was carried out were correct. However, the participant did not realize that the written steps were not systematically sequential in drawing the slices of the plane, during the determination of the problem-solving result. S-1 also checked the results as planned, due to meeting the strategy implementation procedure. Also, the participant stated how the strategy used was discovered by the objectives of the problem, through the order of questions rules in solving the issue. It was also stated that the strategy used was to read and understand the problem first, write down what is known and asked, draw the ABCD.EFGH cube using the affinity axis method, and double-checking from start to finish. Furthermore, S-1 analyzed the suitability of the plans made with the results obtained, by double-checking from the beginning of the work (things that are known, steps, pictures, and final results).

Evaluation Skills of S-1

From the evaluation stage, S-1 correctly answered the question, and obtained the correct results based on the following answer sheet.

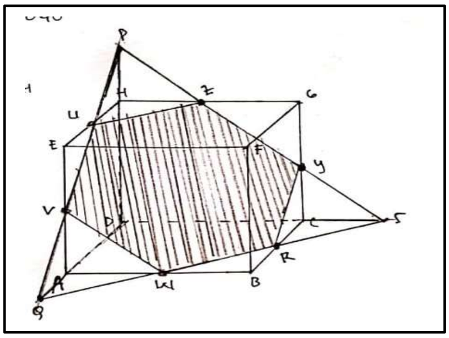


Figure 2. Answer the problem of S-1

S-1 answer and interview stated that there was no other way to check the problem-solving results conducted, than double-checking from the beginning of the work until the final result, which was a plane that cuts the cubes. S-1 also stated that the method used was correct, because it was often used when double-checking the problem-solving results, from the beginning to the end. Moreover, the participant evaluated the target achievement, by carefully examining the results obtained, in order to ensure the correctness of all the results of the work conducted. S-1 also stated that what was carefully examined was known, in terms of location of the points on the line, suitability of the steps with the pieces of the cube, and the cross-sectional planes formed on ABCD.EFGH.

Prediction Skills of S-1

S-1 predicted problem-solving by claiming the correct answer, based on the strategic plan used, solving steps, and the end result. It was also stated that the conclusion obtained after solving the problem, was due to the necessity to have basic knowledge of the relationship of points, lines, and planes, as well as accuracy in drawing spatial slices, especially in cubes. This meant that S-1 tended to need help, in order to solve the problems at hand.

Discussion

The objective of this study was to examine the metacognitive skilss of advanced students in relation to mathematical issues. We achieved this by analyzing their written responses and interview outcomes from a problem-solving assessment. The findings indicated that participants employed their metacognitive abilities. Nevertheless, there were limitations in applying those talents throughout specific evaluation phases. For instance, "I lack the ability to articulate any additional information utilized to address the same issue." The main cause of errors seen by pre-service instructors in addressing mathematics problems was their lack of strategic and procedural expertise regarding cube slices. Furthermore, Cardelle-Elawar (1992) has remarked that in many classrooms, instructors tend to disregard this issue, indicating a lack of awareness. The initial introduction to mathematics is crucial as it facilitates the development of metacognitive abilities. Nevertheless, both participants successfully recorded and articulated the factual information presented in the questions.

The problem-solving abilities associated with metacognitive skills were consistent with the findings of previous studies conducted by Jagals & Walt (2016) and Magno (2010). Later, the step of assessing the participants' monitoring abilities provided a deeper understanding of the methods they employed in creating the cube slices. Furthermore, we observed variations in the outcomes and methodologies used by the participants during this acquisition process. S-1 ensured the accuracy of the solution stages, established the outcomes of addressing the given problems, and acquired verification through written responses. However, despite the accuracy of the acquired results, S-1 overlooked the fact that the written instructions did not follow a systematic sequence for drawing the cube slices and calculating the problem's solution. Additionally, participants utilized monitoring skills to compare the results with the planned strategies to determine if they successfully executed the implementation methods. Monitoring skills are defined as the ability to manage and control cognitive qualities throughout task execution. We use these skills to identify difficulties, modify plans, and evaluate one's comprehension while attempting to complete a task. The actions of the two participants aligned with the assertions made by Desoete (2009b; Son et al., 2020).

The rationale behind initiating a cube intersection was that the spots where the plane and the cube object cross do not necessarily have to form a polygon. We can categorize the intersections as empty when there is no meeting point between the plane and the cube, singular points when the plane only intersects with the cube's vertices, or line segments when the planes only connect at the cube's ends. In this instance, the field does not occupy the inside of the cube. Moreover, polygons typically possess three, four, five, or six sides (Gómez, 2009). Consequently, pre-service instructors found it less challenging to accurately depict the individual sections of the cube, particularly while executing the final steps. Simons et al. (2020) and Tian et al. (2018) have validated this outcome, emphasizing the importance of metacognitive knowledge in mathematical learning and its influence on mathematical performance.

In the skill evaluation step, the participants assessed the level of achievement of the targets. The participants thoroughly examined the collected results to verify the accuracy of each executed step. They ensured that the process aligned with the pre-established approach and verified it through written responses. This activity aligns with the findings of Veenman & Spaans (2005), which emphasize the importance of conducting assessment or monitoring activities at the planning stage to identify procedural and framework problems in action plans. However, no other methods were available to verify the outcomes of problem-solving. Garrett et al. (2006) observed disparities in the ability to determine correct and incorrect responses between the two groups of participants, despite variations in education and age. This outcome had implications for the efficacy of pre-service teacher self-evaluations during the mathematical problem-solving process.

Desoete (2009a), Kesici et al. (2011), and Wang et al. (2021) have found that learners with strong prediction abilities are able to anticipate the difficulty of tasks and adjust their approach accordingly. This allows them to work consistently and efficiently on difficult tasks while completing easier tasks at a faster pace. Furthermore, the ability to forecast enabled learners to link specific types of problems, resulting in an intuitive understanding of the requirements for completing a task and discerning genuine challenges in solving mathematical problems. We encouraged students to integrate their existing knowledge with the assessment data to explore potential outcomes. Moreover, the results showed that the participants exhibited the capacity to predict and create deductions following the resolution of the cube-slicing challenge.

This study covered metacognitive skills such as planning, monitoring, evaluating, and predicting. While there were a few areas that required improvement, the metacognitive abilities tested here were consistent with those of successful problem-solving studies when it came to drawing cube slices. Accordingly, professors should check that their college students' have experience, metacognitive knowledge, and procedural skills before covering the subject of sliced cubes. According to the results, these combinations helped make this study a success.

4. CONCLUSION

The primary goal of this research was to examine, using cube slices, the metacognitive abilities of field-dependent college students'. The descriptor or indicator of metacognitive skills indicated that the participants engaged in comparable activities, including planning, monitoring, evaluation, and prediction. On the other hand, neither party has fully achieved all of the indicators.

The results of this study have important implications for how college students' can improve their metacognitive abilities. The results also highlighted implications for the instruction of factual, procedural, and metacognitive information in problem-solving. While planning the cube-slicing exercises for the teacher training program, particularly for professors, we drew several helpful conclusions from the outcomes and consequences. We derived the results from a small-scale study involving 35 participants from a single private university. The individuals belonged to two distinct cognitive styles in pre-service teacher programs. The study's shortcomings were noted.

Although participants had completed the metacognitive skill task, more research was necessary to shed light on the topic from a broader perspective and identify other issues. Unfortunately, college students' still require therapy and instruction to help them make the most of their metacognitive abilities. Consequently, other educational practitioners were likely to benefit from the intriguing facts offered by observations of the educators' teaching process on mathematical difficulties. We also recommend this study to researchers and instructors who face similar challenges to thoroughly investigate the role of metacognitive knowledge in problem solving

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