

Exploration of Students' Strategic Competence in the Higher-Order Thinking Skills-Based Linear Programming Topic in Terms of Mathematics Learning Styles

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Abstract

This study is descriptive-explorative in nature, employing a mixed-methods approach and aiming to know the students' strategic competence in higher-order thinking skills (HOTS)-based linear programming topics in terms of mathematics learning styles. Six grade XI students of senior high schools in Polewali Mandar, West Sulawesi, Indonesia, were involved in this present study, representing each learning style and strategic competence category. The instruments employed were a questionnaire, a test, and an interview guide. The questionnaire and test scores were analyzed quantitatively, whereas test answers and interview results were analyzed qualitatively. The results showed that the visual learners were unable to formulate problems, were incorrect in representing problems, and were unable to solve them correctly. They tended to misinterpret verbal information as well as involve visual presentations. The auditory learner could formulate problems; however, the auditory learners were not completely correct in representing problems and were unable to solve them correctly. They tended to narrate their strategies and were the best at interpreting verbal information. Meanwhile, the kinesthetic learners were unable to formulate problems, were not completely correct in representing problems, and were unable to solve them correctly. They were the best at representing problems, but they tended to be rigid in performing the strategy.

Keywords: Strategic competence, mathematics learning styles, HOTS.

Received: 15 December 2022

Revised: 28 February 2023

Accepted: 12 March 2023

1. Introduction

The strategic competence is an aspect of students' mathematical proficiency that is important to develop. This competence consists of three abilities, namely, to formulate, to represent, and to solve mathematical problems. Problem-solving abilities are considered one of the 21st century students' capabilities (Kementerian Pendidikan dan Kebudayaan, 2017). The government and other educational stakeholders continuously attempt to ensure that such competences are mastered by students. Therefore, it is important to investigate the students' strategic competence to get insight into their potential for future lives.

Based on initial observation at a high school in Polewali Mandar, West Sulawesi, students in year XI tended not to have adequate and meaningful learning experiences about finding or creating mathematical problems because of learning limitations. Learning limitations were caused by the COVID-19 pandemic, which required students to interact online and also work on mathematical problems that were formulated by teachers or textbooks. Hence, students' activities to formulate mathematical problems from real-life situations were rarely carried out. A complete insight into a student's ability to formulate mathematical problems could be obtained when students find or create the

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problems from existing situations, as stated by Kilpatrick et al. (2001). In addition, the mathematics teacher also admitted that during online learning, only about half of students were capable of three aspects of strategic competence based on his observations. Therefore, to obtain a clear insight into students' strategic competence, an exploration of this issue is needed in Senior High Schools in Polewali Mandar.

Problem-solving is essentially related to non-routine matters where students need a higher level of thinking in developing strategies to get problem solutions. This level refers to higher-order thinking skills or HOTS (Setiawati et al., 2019; Brookhart, 2010). Thus, in this present study, the strategic competence that includes problem-solving was explored with HOTS. In addition, the mathematical topic focused was linear programming because it is close to daily life situations where the core content is about optimizing planning limited by constraints.

In this study, the exploration of the students' strategic competence was based on their dominant learning styles. Learning linear programming online certainly could prevent the students from employing their learning styles; in other words, their learning styles could not be accommodated properly during online learning activities. In order to get the best instructional outcomes, teachers must account for variances in students' learning styles and cognitive processes while designing instruction (Sternberg et al., 2008). Further, Kilpatrick et al. (2001) state that strategic competence correlates strongly with conceptual understanding. This study aimed at exploring the students' strategic competence in the topic of solving linear programming problems viewed from their learning styles.

2. Literature Review

Essentially, the strategic competence covers only two elements, namely, problem formulation and problem-solving (Kilpatrick et al., 2001). This is because the ability to formulate mathematical problems is related to the problem construction in which the new mathematical problem will be devised, while the ability to represent and solve mathematical problems are both covered in problem-solving competence.

The ability to formulate mathematical problems refers to the construction of mathematical problems (Kilpatrick et al., 2001). They define the formulation of mathematical problems as creating or posing mathematical problems based on a given situation. The problems formulated should be mathematical in nature and solvable. According to Brown and Walter (1990), there is an important element in posing mathematical problems, namely, accepting, which refers to the students' ability to understand the situation and the information provided. Meanwhile, Krutetskii (1976) found that students with high proficiency were able to see problems from the information provided and pose them directly, while students with low proficiency needed some directions or were unable to pose them directly.

Hitherto, some studies (see Asy'ari et al., 2020; Firaisti et al., 2013; Kurniayu & Nurjanah, 2020; Sabilah et al. 2018; Syukriani et al., 2017; Wijayanti et al., 2020; and Yulianti et al., 2017) have explored students' strategic competence using predetermined mathematical problems. As a result, the problem formulation capacity is not observable. Although this kind of study could provide some information regarding the processes of mathematical problem formulation, the researcher would be unlikely to gain a more complete insight into the students' abilities in formulating mathematical problems (Kilpatrick, 1987). The competence to construct problems will be evident in problem-posing, where they are provided with situations based on which the problem will be formulated.

The competence of representing mathematical problems is simply the ability to express the problems in appropriate forms, for instance, in numeric, symbolic, verbal, or even graphical expressions (Kilpatrick et al., 2001). Further, Kilpatrick et al. (2001) emphasize that the important aspect the students need in representing problems is a mental image of the problem elements as well as understanding the problem situation. With this image, they could form a representation of the problem that would cover all the main problem elements while ignoring all irrelevant elements. Yulianti et al. (2017), exploring the strategic competence, found that only 8 out of 28 students were able to represent linear programming problems correctly.

The capability to solve mathematical problems as a strategic competence is the ability to find appropriate solutions to the problems carried out after the problem representation stage. Kilpatrick et al. (2001) state that solving a mathematical problem depends on the students' skills in carrying out their problem-solving procedures. Polya (2004)

explains that heuristically, there are four stages of problem-solving, namely, understanding the problem, developing a plan, implementing the plan, and looking back. In this present research, the ability to solve mathematical problems was investigated only from devising plans until re-checking the solution, because the first stage of understanding the problem was set to be observed in the problem representation ability. Flexibility in choosing solution strategies is an additional aspect of problem-solving mentioned by Awofala (2017) who explains that one of the characteristics of students with less strategic competence is not having the skills to flexibly adopt appropriate strategies in solving mathematical problems.

3. Methods

This investigation is descriptive-explorative research using a mixed-methods approach. It is descriptive because it portrays the students' strategic competence, and it is explorative because it explores and seeks insight into the complete strategic competence. This research was conducted at senior high schools in Polewali Mandar, West Sulawesi, initially involving six participants selected from 58 grade XI students. Each category of learning styles was represented by two students, one with low competence and the other with high competence. This tendency (high or low strategic competence of students) is to enrich the findings of strategic competence of students with certain learning styles. Thus, the subjects are visual students with high and low strategic competence, auditory students with high and low strategic competence, and kinesthetic students with high and low strategic competence.

The supporting instruments used in this study were a mathematics learning style questionnaire, a strategic competence test on the HOTS-based linear programming subject, and an interview guide. The instruments were validated by experts. Data collection began by delivering the questionnaire and the strategic competence test to class XI students. The results of questionnaires and tests were scored and then categorized to determine the six students to be interviewed. Further, they were interviewed to explore more of their strategic competence that could not be observed in their written test.

For testing the credibility of the research data, a persistent observation was carried out on the data from the questionnaires and the test. Triangulation was also used to validate the students' test responses, and member-checking was used to validate the students' interview data. The data were analyzed quantitatively and qualitatively. Quantitative data analysis used descriptive statistical analysis, while qualitative data analysis used the interactive method of Miles et al. (2014) which consists of data collection and condensation, data display, as well as conclusion drawing and verification.

4. Results and Discussion

Based on the analysis results of questionnaire data, from 58 students, 13.8% were visual students, 56.9% were auditory, and 29.3% were kinesthetic. So, the majority of class XI students were students with an auditory learning style, where they tended to choose to learn mathematics through listening and activities such as discussing, explaining, and so on.

On the strategic competence test, the students' scores showed that 50 of them were classified as having low strategic competence on the subject of HOTS-based linear programming, while eight other students were classified as having high strategic competence. The results of the descriptive statistical analysis also showed the low score of students' strategic competence, with an average score of 4.06, where the maximum test score was 14. In addition, the variance value obtained was 6.07 and the standard deviation was 2.46, so it can be concluded that student test scores were scattered far from the average value. It means that there were students with high scores and students with very low scores. The table 1 are the results of the student score analysis on each component of the strategic competence.

Based on the table 1, students tended to have low abilities in each strategic competence in solving the HOTS-based linear programming problem. Almost all students were unable to formulate the problem, around 85% of students were unable to represent the problem as objective functions and precise linear constraints, and none of the students found the correct solution to this problem.

Table 1. The Descriptive Statistic Analysis Result of Strategic Competence Components

Elements	The Ability to Formulate Mathematical Problem Score	The Ability to Represent Mathematical Problem Score	The Ability to Solve Mathematical Problem Score
Score range	0 – 4	0 – 4	0 - 6
Mean	0,97	2,17	0,92
Median	1,20	2,10	0,20
Mode	0	1,20	0
Score Total	56,30	125,78	53,30

The six interviewees were selected based on the results of the questionnaires and tests. Furthermore, the six research subjects were validated and interviewed. After that, the analysis of the test answers and interview results was carried out. Following is a description of the strategic competence of students with certain learning styles in HOTS-based linear programming problems.

4.1. The ability to formulate HOTS- based problems

In formulating the problem, students with a visual learning style understood information presented visually but failed to understand verbal information. These results confirm the research findings of Sari and Pujiastuti (2020). Meanwhile, students with an auditory learning style were able to understand all information, both visual and verbal. This is somewhat different from the findings of Sari and Pujiastuti (2020), who found that these students sometimes had difficulty absorbing written information. Meanwhile, students with a kinesthetic learning style only focused on visual information, even though they were able to understand the verbal information given.

Students with a visual learning style were unable to formulate linear programming problems because the problems they built did not have an informational description of the objective function. One of the students admitted that he did not understand linear programming concepts well. Samuelsson (2010) says that the students' strategic competence has a higher correlation with their conceptual understanding compared to other aspects of math skills. Students with an auditory learning style with high strategic competence were able to formulate solvable linear programming problems that could be solved, while students with low strategic competence formulated problems unrelated to linear programming.

Students with a kinesthetic learning style were unable to formulate linear programming problems. Those with high strategic competence constructed problems that tend to be irrational; the information in the problem is conflicting so that it cannot be solved. Meanwhile, students with low strategic competence even formulated problems unrelated to linear programming. This finding is different from the research results of Hikmah and Nuriyatin (2020), which showed that students with visual and kinesthetic learning styles were able to solve contextual math problems.

4.2. The ability to represent HOTS-based mathematics problems

Not all students with visual and kinesthetic learning styles were able to understand implicit item information. This was because students failed to see a pattern of relationships between the information in the problem. Meanwhile, students with an auditory learning style were more capable in this regard. In terms of representation, the students with high strategic competence in each learning style used a more expert approach, namely, by building models. However, when compared among them, the students with kinesthetic learning styles were the most proficient in this approach. The students with weak strategic competence constructed mathematical models as a form of representation of HOTS-based linear programming problems.

In the visual learning style, the students with high strategic competence were mistaken in representing the objective of the problems because they ignored one of the determinants of the objective of the problem in constructing the objective functions. This is in line with the findings of Khairunnisa and Darhim (2020). They found that the students

were still poor at determining the objective model of the two determining factors; there were 80% of students who were unable to do this. This could be caused by their lack of understanding of the relationship between the two factors contributing to objective functions. In addition, these students used visual representation as a tool for representing the problem. Meanwhile, students with low strategic competence represented the problems with an inductive approach and used symbolic representations where the solution was determined from the beginning. Like the character of a visual learner, students used this approach because they wanted to know an overview of the problem's solutions.

In the auditory learning style, students with high strategic competence represented this problem in two stages based on two determinants of the objective functions. In the first stage, students represented the first factor and limited resources in the model, namely, the objective function and linear constraints. In the second stage, students used symbolic representations to express the objective functions. This representation was applied to each value of the objective function based on the corner points. Even though it was complete, the representation was not completely correct due to errors made for the second factor. These errors resulted in the wrong combination of elements optimizing the objective functions. Meanwhile, students with low strategic competence only represented the problems with mathematical symbols, but the representations they built were illogical. This suggests that students were unable to see a mental picture of the elements of the problem (Kilpatrick et al., 2001).

Regarding the students with a kinesthetic learning style, those with high strategic competence represented the problem in two stages, similar to the answer of the students with an auditory learning style. However, in the second stage, the representation was built on the maximum first factor. Thus, the representation was not entirely correct because the combination of elements optimizing the first factor did not result in the optimal value of the objective functions. On the other hand, students with low strategic competence constructed erroneous objective functions due to their inability to understand the implicit information. Moreover, the linear constraints were also wrong due to the same thing. Maharani and Ubaidah (2019) found that a lack of understanding of problem information could lead to an inability to make correct mathematical models. As stated by Kilpatrick et al. (2001), an understanding of the problem along with important information in it is necessary to form a representation that includes all the main elements of the problem. The results are slightly different from those of Sholikhah (2018), who found that only students with a visual learning style were able to create mathematical models to represent linear programming problems.

4.3. The ability to solve HOTS-based mathematics problem

Students from the three types of learning styles had a solution plan that was in accordance with the form of the problem representation. The plan led to wrong answers due to previous errors in the problem representation. In terms of implementing the solving strategy, students with a visual learning style and high strategic competence made errors in finding the coordinate points through which the constraint equation line passes. As a result, the graph was drawn incorrectly, and the corner points of the feasible region were also incorrect. Meanwhile, students with low strategic competence made errors in writing, computation, and reasoning. In addition, students with a visual learning style used visual presentation aids in their strategies.

In the auditory learning style, students with high strategic competence had logical considerations in implementing their strategies. They did not make calculation errors, but they made a mistake in determining the capital due to misrepresentation. Meanwhile, students with low strategic competence made calculation errors in division operations involving decimal numbers. In addition, students with an auditory learning style tended to narrate their strategies in writing.

In the kinesthetic learning style, students with high strategic competence did not make any calculation mistakes, but they were unable to determine the capital value of profits. Meanwhile, students with weak strategic competence made many errors, namely, calculation errors, including elimination procedures to determine solutions to systems of linear equations and the determination of feasible regions and corner points.

Students with visual, auditory, and kinesthetic learning styles did not recheck the solution steps or the solution as a whole. Thus, in general, students of all three types of mathematics learning styles were unable to solve HOTS-based linear programming problems.

5. Conclusion

From the 58 Year XI students of senior high schools in Polewali Mandar, West Sulawesi, Indonesia, the majority of students have low strategic competence in solving linear programming problems based on higher-order thinking skills. In particular, students tend to have low abilities in every component of the strategic competence. The visual students are unable to formulate HOTS-based linear programming problems, represent the problems, and properly and correctly solve problems. Also, they tend to understand visual information but misinterpret verbal information. They tend to use visual representations in their strategies, both in representing and solving mathematical problems. In the auditory learning style, one of the two students was able to formulate linear programming problems. However, the auditory students are not entirely correct in representing the HOTS-based linear programming problems. They are also unable to solve the problems properly. When compared to other mathematics learning styles, the auditory students tend to be better at understanding verbal information, especially implicit information. In addition, it is evident that they tend to narrate their strategies in an orderly and complete manner. Meanwhile, the kinesthetic students are unable to formulate linear programming problems correctly. They are not completely correct to represent HOTS-based linear programming problems and are unable to solve the problem properly and correctly. When compared to other mathematics learning styles, kinesthetic students tend to be better at representing HOTS-based linear programming problems. In addition, they tend to be less flexible in carrying out some of the strategies used in solving the problem. Based on the conclusions above, it is suggested that further research could focus on investigating the learning methods that can improve the students' strategic competence.

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