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Strategic Competence of Senior Secondary School Students in Solving Mathematics Problem Based on Cognitive Style

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Abstract. The purpose of this study was to explore the strategic competence of senior secondary school students in solving mathematics problems. Terdapat dua subjek, satu bergaya kognitif field-independent dan satu bergaya kognitif field-dependent tetapi keduanya memiliki tingkat prestasi belajar matematika yang setara. There were two subjects, one field-independent cognitive style and one field-dependent cognitive style. They had an equivalent high level of mathematics achievement. Keduanya dipilih berdasarkan hasil tes kompetensi matematika dan GEFT (Group Embedded Figures Test). Subjects were selected based on the test results of mathematics competence and GEFT (Group Embedded Figures Test). Kompetensi strategis dapat merangsang perkembangan otonomi dan fleksibilitas dalam diri siswa karena merupakan keterampilan yang sangat dibutuhkan di sepanjang abad 21. Gaya kognitif merupakan kecenderungan siswa dalam mengolah informasi sangat mempengaruhi performance dalam menyelesaikan masalah matematika. Strategic competence can stimulate the development of autonomy and flexibility of students and they are skills which are needed in the 21st century. Cognitive style is the tendency of students in processing informations and it greatly affects the performance in solving mathematics problems. Hasil penelitian menunjukkan bahwa subjek FI cenderung analitis baik pada pembentukan bayangannya maupun pada gambar yang dibuatnya untuk memproses informasi berdasarkan dengan struktur pengetahuannya sendiri (Internally directed). The research result showed that subject FI tended to be analytical both in forming the mental imagination and the picture to process information in accordance with his own knowledge structure (internally directed). Subjek FD kurang analitis dan tidak dapat mengenal bentuk sederhana (konsep matematika) dari bentuk yang kompleks (Exeternally directed) sehingga menerima ide sebagaimana yang disajikan. Subject FD was less analytical and unable to recognize simple form (mathematical concept) of a complex form (Externally directed), so he received the idea as presented. Hasil penelitian ini penting sebagai bahan masukan untuk guru dan pengembang ilmu pendidikan matematika untuk meningkatkan fleksibilitas (Flexibility) siswa dalam keberagaman karakteristiknya melalui penelitian terkait dengan pengembangan bahan instruksi, perangkat dan model pembelajaran matematika. The results of this research are important as input for teachers and mathematics education developers to increase the flexibility of students in the characteristics diversity through the research related to the development of instruction materials and mathematics learning model. Penelitian selanjutnya, sebaiknya melihat bagaimana FI dan FD dapat memberikan penjelasan dan pembenaran atas strategi yang telah diusahakan supaya terlihat lebih jelas bagaimana perbedaan FI dan FD dalam mengkontruksi konsep matematika pada pengalaman belajarnya Further research should study about how the explanation and justification for the strategy that has been attempted in order to look more clearly how constructing mathematical concepts in their learning experience.

INTRODUCTION

Mathematics problem solving has been placed as a center to develop the knowledge, skills, competence and beliefs in mathematics [1, 2, 3, 4, 5] including developing skills in employing a variety of strategies as a solution (flexibility). Stanic & Kilpatrick explain that problem-solving as a context that shows math in real-world situations, problem-solving as a skill in mastering the strategies as individual skills, and problem-solving as a highly creative process [6]. Exercise employing strategies of experience to solve non-routine problems greatly help students establish flexibility

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[2]. Flexibility is an essential skill and necessary in the process of solving mathematics problems [2, 7]. It is one of the skills needed in the current period and throughout the 21st century.

Employing a strategy in solving a mathematical problem involves conceptual understanding that has been built before and also involves the learning experience [2]. The process of integrating conceptual understanding with the problem situation of each individual student differ. Each individual has certain characteristics in processing information to generate various strategic ideas. NCTM [1] emphasizes that students are trained to cultivate their ability to communicate their ideas and understanding through multi-representation and linking mathematical ideas through their application. Therefore, in this study, it is necessary to study how the description of the components of strategic competence in solving mathematical problems. This can be the basis of science to further develop this study, which leads to develop of the quality of education to complement the previous studies about strategic competence and prepare the student to fulfill the demands of skills that must be possessed by students to face the 21st century.

Based on the explanation above, we conclude that problem solving has the major goal, namely to support the students to become autonomous learners. Previous studies had investigated the strategic competence through mathematics problem context in the classroom practices that stimulate autonomy [8, 9, 3]. Ozdemir and Pape [9], for example, their case study on sixth-grade of math class in Medwestern city in United States had identified that the strategic competence could be established and developed by allowing autonomous occur in the learning experience of students. Groves [3], in her study of first-year students in Melbourne Australia of five and six years old, practiced classroom atmosphere that supported the development of strategic competence of students. The classroom practice used problem-based task and instructions to stimulate students to use their own representations and strategies in solving mathematics problems.

Previous studies defined strategic competence as an effort employing efficient strategies while formulating, representing and solving mathematics problems [2, 8, 9, 3]. Ozdemir and Pape [9] defined strategic competence as follows: *"Strategic competence as students' Efforts to regulate reviews their learning behaviors. Therefore, strategic competence includes knowing and Employing strategies to analyze and complete tasks and activities or to solve problems with the goal of learning mathematics content* "(p. 154). Ostler [10] defined strategic competence as follows: "*Refers to the ability to formulate suitable mathematical models and select efficient methods for solving problems*" (P.17). Suh [8] designed the learning process to investigate the strategic competence of students through real-life problems that could be solved mathematically and then the strategic competencies of students were assessed by the following indicators: formulating and carrying out the plan, creating similar problems, solving using appropriate strategies. Kilpatrick et al. [2] define "*Strategic competence refers to the ability to formulate mathematical problems, represent them and solve them*" (p.5). Kilpatrick et al. [2] also revealed that the situation of the problem had to be understood first by building a mental image of its important components to represent it accurately.

Based on previous studies described above, this study concludes that the strategic competence is a mental activity in employing strategies to formulate, represent and solve problem situations. The mental activity can be observed through sub-aspects presented as follows:

TABLE 1. Strategic Competence Aspects

Aspect	Sub-aspect observed
Formulating	What strategy is used to understand the problem What strategy is used to formulate known data/information from the problem situation. What strategy is used to formulate asked data/information from the problem situation
Representing	What strategy is used to model or represent the problem situation.
Solving	What strategy is used to solve

The purpose of this study was to explore strategic competence in solving mathematics problems at eleventh grade of senior secondary high school students based on cognitive style. Cognitive style is the tendency of students to process information [11, 12], in particular cognitive style of *Field Independent* (FI) and *Field Dependent* (FD). Witkin revealed his finding that FI students are internally directed and organize information with their own structures, analyze problems by capturing all the important elements of the context, and accept the idea strengthened by the analysis first while FD students are externally directed and easily influenced by salient features, observing the problem relatively in a global fashion and accepting the idea as presented [11]. As described above, FI and FD students have different characteristics in processing information. Therefore, this study compared the strategic competence of FI and FD students in solving mathematics problems.

METHODOLOGY

Subjects

The subjects were the eleventh grade students with high mathematics achievement. The subjects were two students; one was with a cognitive style of *Field Independent* and another one with cognitive style of *Field Dependent*. Both had an equivalent level of mathematics achievement.

Instruments

This qualitative study used main instrument and aid instruments. The aid instruments to obtain the characteristics of appropriate subjects and collect data. The main instrument is researcher myself. The aid instruments were a test of mathematics competence, GEFT (*Group Embedded Figures Test*), unstructured interview guide and non-routine task problem. The test of mathematics competence was constructed from questions of National Examination (UN) in 2013, 2014 and 2015 and had been converted into an essay test to know the mathematics achievement of students. GEFT (*Group Embedded Figures Test*) was used to determine the student's cognitive style. The unstructured interview guide comprised of questions to dig up sub-aspects of strategic competence. Non-routine task problems as a mathematical problem.

Procedures

Through non-routine problem and interview guide, subjects were interviewed to investigate sub-aspect of strategic competence in the process of mathematics problem solving. Non routine math problem was a contextual math problem and it has never been seen and solved. The problem could be solved by more than one different methods and approaches. In addition, it also involved some math concepts, such as a circle and area of a circle, a square and the area of a square, a triangle and the area of triangles, Pythagoras and trigonometry as the completion solution and it required the heuristic approach. Triangulation of time was used to generate the credible data. Data from interview and task were categorized, reduced, analyzed and interpreted to make conclusions.

RESULTS

Individual interview based on results of task had been conducted to raise student autonomy in employing strategies as the right solution. This study focused on how the subject employed strategies to formulate, represent, and solve problem situations. Here will be explored the results from interview and task data about the aspects of formulating, representing and solving with each sub-aspect.

Formulating

FI understood the problem situation by reading and imagining. FI read twice text until he captured the core information problem then imagined it to shape a clear mental image. FI captured that cable length of 80 meters was the core information. FI considered that the location of the power source, the existence of the warehouse, and the edge of land affected the length of cable forming the land area in which the grass could be mowed. FI formulated the known informations by retelling them in his own language without looking at the text and intimated them by using concrete objects nearby such as the papers as the land, forming a square with his fingers as the warehouse and putting a pen as the cable length. FI formulated the information asked by rotating one end of a pen and curbing its other end at the point of the right front corner of the warehouse. The presence of the warehouse and the edge of land also affect the cable so FI created a land area in which the grass could be mowed from four parts: 1) a half circle; 2) a quarter circle; 3) a twelve circle; and 4) a right triangle.

FD understood the problem situation by reading and imagining. FD read twice the problem situation, so he received all the information and imagined them to acquire the shape of them. FD captured that the lawnmower with a cable length of 80 meters and the existence of the electricity source would form a land area in which the grass could be mowed that was circle form. FD formulated all known information by retelling them in his own language without looking at the text. FD drew illustrations on paper about all of the problem information and then enabled the cable length to reach in to the front, to the left and to the right side so as to form a half circle area. FD did not consider the presence of the warehouse and the edge of land, so that FD was confused to decide what form in the other side of the reachable area besides the a half circle area that was created in the beginning.

Representing

FI represented the land area in which grass could be mowed to four parts (see Fig. 1): 1) A half circle area with its radius of 80 meters; 2) a quarter-circle area with its radius of 40 meters; 3) A twelfth circle area with its radius of 80 meters, and 4) A right triangle area. Then FI created the symbol representation, which is sum the area for each parts.

$$\left[\left(\frac{1}{2}\pi 80^2\right)+\left(\frac{1}{4}\pi 40^2\right)+\left(\frac{1}{12}\pi 80^2\right)+\left(\frac{1}{2}40\sqrt{3}\ 40\right)\right]$$

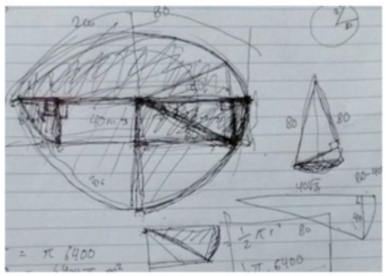

FIGURE 1. FI representation

FD represented the land area in which the grass could be mowed, namely full circle, into three parts (see Fig. 2*):* 1) a half circle with its radius 80 meters; *2)* The land area that was located on the left of the warehouse (unrecognized form); 3) The land area that was located on the right warehouse (unrecognized form). FD only represented the area of a half circle into $\frac{1}{2}\pi\, 80^2$ and did not know the formula for determining the area of the unrecognized form.

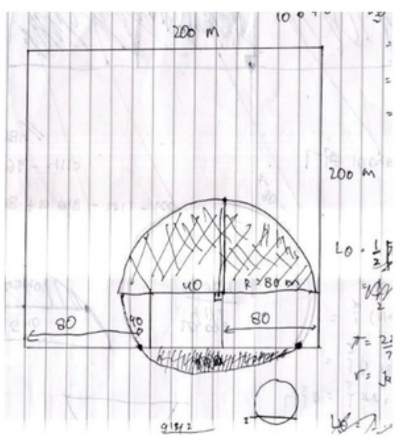

FIGURE 2. FD representation

Solving

FI had a tendency to analyze the picture for acquiring the right solution. FI ensured that every part of the overall picture was in the right solution by paying attention on the picture that had been made. FI focused on paying attention on each part of the picture by separating one part of the overall picture to be able to recognize the right solution, although FI drew every part twice separately on different sides of the paper. For example, the land area on the right warehouse was analyzed by dividing it into two parts by making one line repeatedly and then separating each part of the overall picture to analyze them repeatedly (see Fig. 1). After finding the right solution, FI then used the formula that was appropriate to the concept used. FI completed them by using the correct formula and obtained appropriate final solution.

FD had a tendency to receive information as it was presented without analyzing it first. FD less analyzed that the existence of the warehouse hindered the cable to form the reachable area on the left side of the warehouse and the right side of the warehouse. FD was not internally directed that the land on the left of the warehouse could be formed as a quarter circle. Likewise, the land on the right of warehouse, FD did not recognize what method used as the right solution. FD also considered how to determine the circle area of radius 80 meters, which was outside the land. FD planned that to determine the land area which allowed the grass to be mowed was the area of all the circle of radius 80 meters minus the area of warehouse plus the circle area that was outside the land, as shown below:
[The land area that the grass could be mowed = the circle area with a radius of 80 meters - (the warehouse area + the circle area with a radius of 80 meters which was outside the land)]
Because the FD did not recognize the solution of part of the circle area that was outside the land, he finally gave up and declared that he did not understand more about the next solution.

Discussion

This study explored the valuable finding related to perform strategic competence in solving mathematics problems of students FI and FD. The mathematical performances were more influenced by tendency to process the information, hence the strategic competence of the cognitive-style students of the FI and FD are majority different. Differences were seen when formulating, representing and solving the problem. Here will be discussed some of these differences.

FI and FD had a difference in formulating the known and asked information. To understand the problem situation, FI and FD used reading and imagining strategies for receiving the known and asked information as well as shaping and generating a mental image, considered and determined the core information. The mental image was formed based on how information was received and associated with the prior mathematical knowledge and learning experiences while solving a problem. Furthermore, the mental image was clarified by making representation and then using mathematics to reach a final solution [2]. FI formulated the problem situation by exhaustive consideration correctly. While, FD was functioning core information but did not consider the structural relationship within the problem. FI more expert problem solver than FD [12]. Besides that, these results are consistent with the results of research [13] which showed that mathematical performances are predicted by cognitive style FI and FD.

Representation gives an overview of how the students' understanding of the problem situation and understanding the concept [9]. When students build mental images based on their understanding on the problem situation and the understanding of the concept, they are able to better convert them to the right representation [2]. FI achieved the representative form of a complete and correct picture, while FD achieved a picture representation that was incomplete and incorrect. It was similar to the form of symbolic representation. Both FI and FD showed their autonomy in using mathematics as a solution. These results in line with [3, 9] which described that student decided their own representation to promote their understanding and autonomy. This finding also in line with the research result of Holmes et al. [12] which indicated that FI had a higher score than FD on mathematics achievement. Moreover, this is in line with Kuo et al. [11] that FI was internally directed and the FD was externally directed.

Solving the problem is the effort to find the right way to achieve a certain goal. FI tended to use analytical strategy to solve a problem, while FD tended to receive information as presented and less used analytical strategy to direct to the right solution. These results in line with the results of research [11] which show that analytical and active learning approaches tended to be preferred by FI, while FD were inclined to employ global and passive learning strategies. FI analyzed the situation by using the pictures and separating each part of the whole picture, in line with the description of Charles, Lester & O'Daffer that one of the strategies to solve mathematical problems that can be used is drawing [7].

CONCLUSION

Mental activity in solving non-routine contextual problem and through interviews to dig up sub-aspects of strategic competence can show the strategies used by subjects FI and FD in formulating, representing and solving mathematics problems. The strategy is one manifestation of mental activity that shows the autonomous nature in deciding the right solution. Based on cognitive style, it showed that subject FI tended to be analytical both in mental imagination and in the picture he made to process information in accordance with his own knowledge structure *(internally directed).* Subject FD was less analytical and unable to recognize simple form (mathematical concept) of a complex form *(Externally directed)* so he received the idea as presented. The results of this research are important as input for teachers and mathematics education developers to increase the flexibility of students in the characteristics diversity through the research related to the development of instruction materials and mathematics learning model. Further research should study how the explanation and justification for the strategy that has been attempted in order to look more clearly how constructing mathematical concepts in their learning experience.

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