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Categorization Of Students' Systemic Thinking In Solving A Decision Making Problem

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Abstract

The purpose of this study is to explore categories in students' systemic thinking in solving a decision-making problem. This study is an explorative study using a qualitative approach. The subjects of this study were students of Teacher Education for Madrasah Ibtidaiyah Department, the State Islamic University of Malang who applied in the education statistics course. Data collecting was done by using the think-aloud method and in-depth interviews based on the resulting paper on decision-making problems that had already been given to the subject. The instrument used in this study consists of two types, the main instrument, and the supporting instrument. The main instrument is the researcher himself. The supporting instrument in this study consists of a paper on decision-making problems, an audiovisual recorder, and a guideline for interviews. Paper of decision-making problems is validated by the expert in mathematics education and mathematics. This instrument is tested on students in order to get the criteria of empirical validation. Based on the result of this study there are three categories of systemic thinking, global systemic, pseudo-global systemic, and local systemic.

Keywords: systemic thinking, statistics, decision making, problem-solving, categorization.

INTRODUCTION

Decision-making needs reasoning or high-level thinking, starting with an analysis and synthesis. Basically, decision-making aims for optimizing a value or another measure that is related to risk and benefit. In this case, decision-making only notices on rationality aspect which gives the best decision result, without considering the psychological and sociology aspects (Nielsen, 2009; Gigerenzer & Selten, 2001).

Verschaffel, Greer, and Corte (2000) stated that decision-making is a verbal description of a problem situation with one or more questions. The solution will be found by applying mathematical operations from numeric data that are available in the problem statement. Decision-making is a mathematical problem formed in a sentence that illustrates daily activities (Ashlock, 2003). Decision-making is a group of sentences describing a "real-life" scenario where problems need to be solved mathematically.

In general, the decision-making problem is an application of mathematical and statistical concepts. A how decision making on giving the best and most rational choice is produced from the analysis of mathematics and statistics. Fitzsimons (2001) stated that mathematics and statistics are important in decision making. However, usually, statistical learning is presented in conceptual and procedural ways, from the school level up to the university level. It is rarely linked with decision-making problems Statistical learning needs to take the real meaning in daily context. Idea and patterns of categorization are already used in decision-making (Brown &

Coles, 2003). This shows that statistics on the categorization aspect is needed in decision making.

Decision-making is close related to the process of problem-solving. Decision-making is a structurally and complexically kind of problem-solving, including problems in design and policy (Jonassen, 2012). The process of problem-solving can be done with these steps: 1) represent the problem, 2) explain the situation using a model, and 3) formalize the situation (Nathan, and Kinsth, 2004). This shows that decision-making also can be said as a process in problem-solving.

Presentation of statistical concept that involves real data will give a chance to understand the mathematical relationship based on statistical concept, display, and procedure (Burrill & Romberg, 1998; Garfield & Gal, 1999). Clearly, this will give experience to a college student in applying mathematics and statistics to real-life problems, including decision making. Usage of data in a meaningful problem-solving context is a key aspect of the program that is designed to introduce students reasoning with data (Watson & Moritz, 2000). This election of context is one of criteria in designing the task that is used in this study.

Problem-solving decision-making needs systemic thinking. Systemic thinking is started by deciding the elements or identifying all elements of a problem. In the beginning, Daryani and Ardabili (2014) said that all of the elements in the system must be identified. Meanwhile, Barlet (2001) said that in order to identify a problem, the problem has to be cut into several smaller parts. This shows that problem identifying in systemic thinking must pay attention to all elements of problem, no element that left behind.

Elements of problems are connected to each other or even the connected elements will affect the other elements or group of a few elements. Problem is not only formed by elements individually, but also by the network that connects each of them. According to Espejo (1994), one of the systemic thinking indicators is understanding the interactive process that denotes the integrity of some levels. Grouped elements are placed together by a new method (Haase, 2010). It means we have to understand how the elements work together, so then we can find the pattern at the part of that element. Systemic thinking is an understanding of mechanisms that underlie the previous process.

Determining the appearance characteristics or a pattern of complex problems focus on systemic thinking. As said by some researchers (Johanessen, 2011; Barlett, 2001; Körppen, 2011), the most crucial component in systemic thinking is finding a pattern formed from elements that interact with each other (focusing on patterns of interaction). Trying to find an understanding pattern and changing to a thorough understanding is called by Barlet (2001) finding a central theme or common theme in all of sub-theme. In the end, common a pattern that formed is will give a conclusion in order to make a decision. If it is arranged briefly, systemic thinking is started by denying, analyzing, problem problem-solving decision-making (predicting) what is reasonable with the system.

Systemic thinking has been studied by some researchers with different terms. Sterling (2003) used ‘whole the systems thinking’ term. Tien (2012) used the ‘think globally, act locally’ term. Holt (2010) used ‘Theory of Constraints (TOC)’ term. Sturmberg (2014) used Systems and Complexity Thinking term. Raymond (2014) used the Systemic Thinking versus Systemic Change term. Jereb, et al (2013) thought that systemic thinking can be understood as a way of thinking which considers elements and overall interdependence, so then it forms a pattern that complete completes and together lead to reach a certain goal with a simple action. The basic assumption in systemic thinking is based on a concept of ‘Everything interact with each other and the surrounding’.If we want a result that is

different from the situation, it can be done by changing the supporting system of situation, until it can give different output.

Some of the studies reviewing systemic thinking and mathematics are Giacalone and Spagnolo (2002), Lemut (1999), and Khisty (1997). Studies of systemic thinking that have already been done by Khisty (1997), Lemut (1999), Giacalone, and Spagnolo (2002) are not yet in the categorization of systemic thinking cognitively, but it indicates the existence of systemic thinking. Therefore, this study will explore the category of students' systemic thinking in solving decision-making problems.

METHOD

The type of this study is a qualitative explorative study. In this study, the researcher tries to examin the subject thoroughly, carefully, and profoundly thoughts in order to get the idea of systemic thinking in solving decision-making problems. This study was done at the Islamic State University of Malang and the subject was third-semester students. This study aims to explore the categories of systemic thinking in solving decision-making problems, so then the students are expected to solve the problem the in think aloud method. Students revealed all of their thoughts loudly during solving decision-making problems.

An instrument used in this study consists of two types, the main instrument, and the supporting instrument. The main instrument is the researcher himself. It is caused by the fact that the researcher conducts as a planner, data collector, data analyzer, data interpreter, and reporter of study results. The supporting instrument in this study consists of a paper on decision-making problems, an audiovisual recorder, and a guideline for interviews. Paper of decision-making problems is validated by the expert in mathematics education and mathematics. Those validations are done to fulfill the criteria of content & construction validity. Criteria of validity is identified in 4 components (1) content conformity, (2) construction of theory, (3) suitability of work guide, and (4) suitability of problem language. This instrument is tested on students in order to get the criteria of empirical validation. There are two methods in order to check the credibility of data, observation of think aloud process continuously and consistency & triangulation.

RESULT

Based on the analysis of 28 subjects' results on solving decision-making problems, observation of thinking aloud, and in-depth interviews, there are three categories of systemic thinking, 1) global systemic, 2) pseudo-global systemic, and 3) local systemic. Based on all data of those subjects, eight (8) subjects are categorized into global systemic, four (4) subjects are in pseudo-global systemic, and the rest (16 subjects) are categorized into local systemic. Following is the explanation of characteristics in each systemic thinking categorization.

Global Systemic Thinking

Global systemic thinking happens when the subject solves the decision-making problem and follow the step of systemic thinking. Subjects identify the elements of the problem, decide the sub-system, decide the system, and then make a decision. In the beginning, subjects used their own scheme to identify elements of the problem. In identifying the problem, subjects pinpointed the goal of the problem clearly. Subjects answered what was asked by the problem. G1 subject answered that the goal of the decision-making problem from the task is to decide on three groups of restaurants with criteria of taste, place, and price. The following is a part of G1's statement when thinking aloud session.

G1: .... the thing that asked is to find three restaurants with criteria as follows: taste, cozy place, and cheap price.

Next, the subject in this category decided on the elements of the problem clearly, by assigning a value of each restaurant from the data of the decision-making problem.

At the sub-system stage, subjects in this category determine a strong relationship between problem elements in each of the subsystems. Then, subjects show a pattern between elements in the form of rules such as ranking, classifying, categorizing, and giving value for each category. Subjects connect the value of a restaurant with the value of other restaurants. This is according to G3's statement when a session of think aloud.

G3: Bu Mie Restaurant with a score of 47 is higher compared with the score of 43 owned by Warteg Restaurant. The value of Bu Mie Restaurant is higher than Warteg Restaurant, so then the taste of food from Bu Mie is more delicious than Warteg.

Thereafter, at the step of system decision, the G3 subject connects each of subsystem. Subject determine relationships between elements that form a common system as strong relation. G3 subjects form a pattern or relation rule such as ranking, classifying, and categorizing. This appeared in work result of G3 in solving decision-making problems (Figure 1) as below.

Rumah makan	Rasa enak	Tempat nyaman	Harga murah	TOTAL
Warteg	4	1	4	9
Bu Mie	4	2	2	8
Wong jowo	2	4	2	8
Mak Lek	3	1	4	8
Pak kosim	2	3	3	8
sejahtera	3	1	4	8
murah	1	3	1	5
Podo tresno	4	4	2	10
Padang	1	2	1	4

Rekomendasi Penilaian Restoran

1. Rumah makan sangat baik
   a. Podo tresno
   b. Warteg
2. Rumah makan Baik
   a. Bumie
   b. Wong jowo
   c. mak lek
   d. Pak kosim
   e. sejahtera
3. Warung makan kurang baik
   a. Padang
   b. Murah

Figure 1. Decision making of G3 subject

G3 result in categorizing of the common system is a prediction of result in giving decision. In this step, subject connect the value from each criterion by combining all values of each restaurant. Subject compares the total value with each other so it forms a relation pattern in the form of rules of ranking, classifying, and categorizing. And then from that it becomes 4 categories, very good, good, enough, and bad restaurant. After that, the subject changes it into three categories based on the question asked.

Pseudo-Global Systemic Thinking

In this category, the subject identifies elements and goal of problem clearly. Subject of GS1 state that the goal of decision-making problem is to find three groups of restaurants based on three criteria in each restaurant. The following is a snapshot of the GS1 subject statement at session of think aloud.

> GS1: e ... it is asked three good restaurants with criteria for taste, place, and price of restaurant.

Furthermore, GS1 links the elements of the problem, that is restaurant scores with weakly. Subject of GS1 mentioned the value of the restaurant but did not understand the meaning of the value of each restaurant. This shows that the subject identifies elements of problem in a pseudo-global manner.

Subject connect the elements in each subsystem very weakly, so that the pattern of relationships between elements is very weak. In this case, the subject has a pseudo understanding, i.e. the subject mentions the elements of the problem but cannot explain the meaning of the problem element. The subject did not bring up the pattern of relationships in the form of rules for ranking, classifying, and categorizing. Following is an excerpt of GS2 statement when think aloud session.

> GS2: .... in this data, value of Bu Mie restaurant is 47 while the value of Warteg restaurant is 43. 47 is higher than 43, but what does that mean .....

At the stage of determining the system, subject directly connect between subsystems. Subject of GS2 immediately added up the value of each restaurant. Then, subject of GS2 associated the total value of each restaurant with the rules of ranking, classifying and categorizing. Subject grouped all restaurants into three groups, namely very good, good and bad restaurants. This is supported by footage of GS2's work in solving the problem of decision making as shown in Figure 2 below.

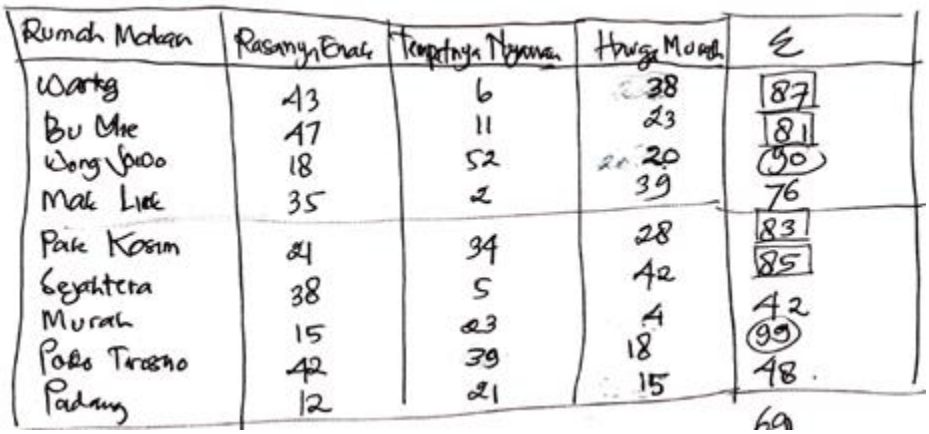

Figure 2. Decision making of GS2

Subject ignores the subsystem stage and skips to stage of building common system. At the stage of determining the common system, subject connects the subsystem by bringing up the pattern of relationships between subsystems with the rules of ranking, classifying, and categorizing into a very good, good and bad restaurant categories.

Local Systemic Thinking

Initially, subject L4 identified all elements of the problem. Then, L4 determined the purpose of the problem. However, the identified goal is less clear. Subject gave a meaning that restaurants who have a taste of food are divided into three groups, namely restaurants that have very good taste grouped as excellent restaurants, restaurants that have good taste grouped as good restaurants, and restaurants that have bad taste grouped as bad restaurant. Likewise, the subject L4 also gives the same meaning to a restaurant by the criteria of place and price. The following is an excerpt of L4 subject statement when think aloud session.

> L4: Here we look for three groups of restaurants, which are very good, good and not good. Means, e .... a very good restaurant is a restaurant that tastes very good, a good restaurant is a restaurant that tastes good, a restaurant that is not good is a restaurant that tastes bad, and .....

Subject L4 clearly identifies elements of problem. Subject mentioned all the restaurant values in the data.

At the stage of determining subsystems, the subject determines the relationship between elements of problem and states the rules of the relationship between it in the sub-system. The subject connects values between restaurants very strongly. This strong relationship is shown by the subject with connecting each value for all restaurants that provides a pattern or rules in forming subsystems, namely ranking, classifying, and categorizing into three groups of restaurants. Likewise, in the same way the subjects grouped three restaurants by place and price criteria. This is supported by footage of L4's work in solving decision-making problems as shown in Figure 3 below.

Figure 3 Decision making of L4 subject

At the stage of determining the system, L4 subject did not connect elements between subsystems. Subject made a decision based on the results of categorizing at the stage of determining the sub-system, namely a group of restaurants with a very good taste as a group of very good restaurants, restaurants that have good taste as a group of good restaurants, and restaurants that have a bad taste as a group of bad restaurant. Likewise, subject also made the decision for a restaurant with criteria for place and price, each into three groups, which is very good, good, and not good in the same way as the one before. The subject determines the decision based when the subsystem is formed.

DISCUSSION

Systemic thinking is very necessary in the process of solving decision-making problems. Decision making must be based on systemic thinking that gives decision makers the opportunity to overcome problem situations in the context of a complete system (Yurtseven & Buchanan, 2016). One's judgment in decision making is based on comparisons between pairs of data encountered (Sut, 2012). Decision making is the result of a systematic cognitive process that leads to the choice of actions among several alternatives.

In solving decision-making problem, students use a scheme that is already owned. Students follow the stages of systemic thinking. Students solve problems starting with identifying problems, determining subsystems, determining common systems and finding solutions to predict in making a decision. This is appropriate with the statement of Arnold and Wade (2017) which shows that in systemic thinking there are ways to simplify and understand structures that support the ability to communicate complex systems in simpler and easier ways. From research findings, three categories of systemic thinking consist of: systemic global, pseudo-global systemic, and local systemic develop previous research findings (Kisty, 1997; Lemut, 1999; Giacalone & Spagnolo, 2002) which show the existence of systemic thinking.

In the systemic global thinking category, students solve problems by reading through the whole problem. Students directly mention the purpose of the problem that an agent asking for

advice to group the restaurant into a very good, good, and bad restaurant categories. Students mention the purpose of the problem clearly. Based on the understanding process, students in this category are included at the highest level of perspective in understanding the problem (Krulik, 2003), by integrating all the information available from reading texts and prior knowledge.

In forming subsystems, students directly link the known elements of a problem with each other. Students connect the value between each restaurant at the taste, cozy place, and cheap price criteria. If the value of the restaurant is higher than the other restaurant, then the taste of the cuisine from the restaurant is better than other eateries. The subject compares the value of each restaurant and sorts it to the value of the restaurant as the most delicious restaurant to a poorly priced restaurant. Thus, the subject can finally sort or rank the value of each restaurant. Next in classifying the ranked value, subject do it by truncating the data of the ranked value using the mean value. Statisticians often think about the mean as a point on the number line where the data on both sides of the point is balanced (Walle, 2011).

At the stage of determining the common system, students connect each subsystem with others and form a pattern of relationship between subsystem elements by the rules of ranking, classifying, and categorizing into a very good, good and less good restaurant categories. Because it started with the formation of a very strong subsystem, students can connect each of the subsystem so then it can bring up the pattern of relations between subsystems. In accordance with the statement (Barlet, 2001) that the overall understanding of the problem will elicit common patterns or common themes throughout the sub-theme. In addition, students build a relationship of problem understanding and knowledge that has been possessed to provide rationality for choosing the right strategy in decision making. The satisfaction factor is a key element of high-level cognition that is often formulated using recurrent neural networks and is used to study reasoning, judgment, and decision-making (Bhatia & Golman, 2019).

The relationship between the elements in determining the common system occurs very strongly. This is indicated by the student's series in building a common system. This system according to Doerr and English (2003) is a mathematical system to give a decision. At the stage of determining this subsystem, students build relationships between elements of problems in their understanding & knowledge and the relationship between them to provide rationality in choosing the right strategy. In understanding the problems, it is related to what is known, asked (purpose problem), and the meaning of the word. While the knowledge that owned before is related to the selection of strategies used. The strategies used by the students are rangking, classifying, categorizing, and giving weights or values. Argawal & Mazumder (2013) found that an individual with the higher scores of mathematical tests, substantially less likely in incorrect decision-making related with the data. Solve decision making problems about data, it needed to sort, calculate, classify and estimate as the basis of mathematical ideas.

In the category of pseudo-global systemic thinking, students directly refer to the purpose of the complete problem that specifies three groups of restaurants, very good, good, and bad restaurants when understanding the problem. Students understand the problem by reading known elements and integrating all existing information by linking previously owned knowledge to a simple analytic thinking. In addition, students understand the problem by using a direct meaning strategy. According to Hegarty, Mayer, and Monk (1995) the strategy done by building a representation of the problem by selecting the numbers and the key statements

in the problem for the calculation that will result an answer that lack qualitative representation of the problem. This makes the process of building a representation to understand the problem less than perfect. In the stage of forming subsystems, students determine the element of the problem very weakly, so that it is also very weak in determining the relationship between elements and subsystems. In this category, students follow the stages of systemic thinking incompletely. In this category, students find solutions and predict by making irrational decisions.

In solving the problem of decision making, students' thought processes in the local systemic category are using their own schemes and incomplete thought of structures. At the stage of determining this general system, students connect between subsystems in weakly way, forming a pattern of relationships between elements of the subsystems that are very weak too in order to make rules of ranking, classifying, and categorizing of all restaurants into very good, good and bad restaurants. Because of the students' understanding in the purpose of the problem is unclear, the categories of taste very good, tasty, and not good are classified as very good, good, and not good restaurants, so the category of restaurants with places that are very comfortable, convenient, and less comfortable classified as a restaurant group that is very good, good, and not good. The results of this study are in accordance with the findings of Lutz & Boucher (2016) which show that the problem contextualization process determines a comprehensive decision method to produce data-based solutions. In this category, students find solutions and predict by making irrational decisions.

CONCLUSION

The results of this present research shows that students' systemic thinking in solving data-based decision-making problems can be categorized into three categories, namely global systemic thinking, pseudo-global systemic thinking, and local systemic thinking. In the global systemic thinking category, students have a complete structure of thinking, started with mentioning the goals of the problem and elements of the problem, mentioning the elements of the problem in the sub system and showing a strong relationship between the elements in the sub system, stating the relationship between the elements in the sub system with the rules: ranking, classifying, categorizing, and giving value/weight, mentioning the problem elements in the system and showing strong relationships between elements in the system, and expressing the relationships between elements in the system with the rules: combining values or weights, ranking, classifying and categorizing.

Meanwhile, in the pseudo-global systemic thinking category, students have incomplete thinking structures at the stage of mentioning the very weak problem elements in sub-systems and connecting weak relationships between weak elements in sub-systems in order to show the rules for expressing relationships between elements in sub-systems. Whereas in the local systemic category, students have incomplete thinking structures, students mention elements of problems in sub-systems and call strong relationships between elements in sub-systems but are very weak in connecting between elements of the system so that they do not show rules for expressing relationships between elements in the system.

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