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Developing Students' Analogical Reasoning Through Algebraic Problems

Siti Lailiyah[1], Toto Nusantara[2], Cholis Sadijah[2], Edy Bambang Irawan[2]
[1]Mathematics Education, Universitas Islam Negeri Sunan Ampel, Jl. Ahmad Yani 117 Surabaya
[2]Mathematics Education, Universitas Negeri Malang, Jl. Semarang 5 Malang
E-mail: siti03_math_its@yahoo.com

Abstract: This study aims at discussing the understanding and definition of analogy reasoning ability including the example of how analogy reasoning ability is formulated in the form of analogy reasoning components and its indicators. This study was a qualitative design research. The data obtained in this study was collected from Mathematic assignment exercise sheets. The source of the data was obtained from think alouds, transcribed interview, and video during assignment completion and interview. The data obtained, then, were analyzed using interactive qualitative analysis technique. The result of this study was examined and described qualitatively. In accordance with the theoretical framework established, the results of this study are described in three groups classification which possess different characteristics such as internal structurization, connective external structurization, and extension external structurization.

Key Words: competence of reasoning, analogy reasoning, algebra problem

Abstrak: Tujuan penelitian ini adalah membahas pengertian dan definisi kemampuan penalaran analogi disertai dengan contoh bagaimana kompetensi penalaran analogi tersebut dirumuskan dalam bentuk komponen-komponen penalaran analogi serta indikatornya. Jenis penelitian ini termasuk penelitian kualitatif. Data yang dikumpulkan dalam penelitian ini berasal dari data hasil lembar tugas matematika. Sumber data dalam penelitian ini berasal dari hasil *thinks alouds*, wawancara yang ditranskripkan, dan video selama subjek mengerjakan lembar tugas serta wawancara. Data yang telah terkumpul dianalisis dengan menggunakan teknik analisis kualitatif dengan model teknik analisis interaktif. Hasil penelitian ini dikaji dan dideskripsikan secara kualitatif. Berdasarkan kerangka teori yang dibangun, hasil penelitian ini dipaparkan dalam tiga kelompok yang memiliki karakteristik berbeda yaitu penstrukturan internal, penstrukturan eksternal konektif, dan penstrukturan eksternal ekstensi.

Kata kunci: kemampuan penalaran, penalaran analogi, masalah aljabar

The end of 2015 escorted Indonesia to the door of ASEAN Economic Community (AEC) which started coming into effect henceforward. Not only does the AEC clearly indicate stronger cooperation and integration among members of Southeast Asia, the prevalence of an open competition is inevitably implied as well. This is so, for the main purpose of its establishment is to make ASEAN as a single market and equally competitive production base characterized by freer capital flow, freer flow of investment, services, goods and particularly skilled labor. With regard to the labor market, the AEC certainly encourages the flow of human resources to competitively penetrate into it. It plausibly suggests that the country, providing its people with educational qualifications and high competitiveness, is to seize a better opportunity, with regard to the labor supply in the Southeast Asia particularly.

According to data provided by the Indonesia Statistics Agency per August 2013, the number of labor force was about 110.8 million. Indeed, referring to Indonesia educational level system, the labor force is dominated by employment that attain on elementary school level. They reach about 52 million or 46.93% of labor force in labor market. This number nearly constitutes half the total. Moreover, the employment that attain on junior high school reach about 20.5 million (18.5%) and about 17.8 million (16.1%) on senior high school. The lowest rate of employed by education is

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in university level on 6.83% or about 7.75 million people, not to mention graduate diploma on 2.63% or about 2.92 million.

In comparison to that, according to data provided by Department of Statistics Malaysia (DoSM) in 2012, the number of labor force in Malaysia was about 13.12 million, 55.79% of which constitutes employment that attain on senior high school level. They reach about 7.32 million. The rest are from tertiary education reaching about 3.19 million (24.37%). Take, for example, another member of ASEAN such Singapore, the number of labor force of which reached about 3.22 million pertaining to World Bank in 2012. This number is mainly composed of employment attaining on senior high school (49.9%) and university level (29.4%). Therefore, in contrast to both Malaysia and Singapore, almost 80% of the labor force of which is dominated by employment attaining high school or university level, it can be seen that low skilled labor, on the other hand, constitutes almost half of Indonesia labor force by 46.93%. It likely implies that Indonesia have not yet made ready for the AEC which brings about stiff competition, particularly with regard to the labor supply.

In response to such demands, education indubitably faces challenges of yielding highly skilled and competitive labor. Referring to the 2013 curriculum, it is to emphasize on building students' characters, developing relevant skills that promote productivity, creativity and innovation, and fostering cognitive skills, all of which are based on the students' interests and needs. In other words, fostering moral strength, skills and knowledge is of paramount importance. However, the main problems lie in providing contextual learning environment and material.

The education system should place a greater emphasis on offering relevant skills required to face the economically competitive era and on promoting analytical skills or reasoning. The analytical skills require a way of reasoning to solve complex problems. However, understanding on reasoning skills, particularly on analogical reasoning, is often perplexing due to its various definitions and implementation in the class. Therefore, this paper is projected to further discuss the definition of analogical reasoning, to provide clarity, the process of which is supported by examples on how it can be formulated into reasoning components and indicators.

Analogical Reasoning

Reason, according to Indonesian contemporary dictionary, is defined as an activity that allows ones to think logically or simply as range of one's thought (Peter & Yeni, 2002). In the dictionary of psychology by Chaplin (in Kartono & Kartini, 1989), reason is defined as "the totality of the intellectual processes involved in thinking and problem solving activities". Moreover, pertaining to Indonesian dictionary, reasoning is defined as "the process of thinking based on observation of the senses to draw a new proposition, previously unknow, by forming similar propositions reasonably deemed to be correct" (Department of Education, 1990). Germane to the above definitions, it can be concluded that the notion of reasoning deals with logical thinking and problem solving. Reasoning in this study is defined as a mental activity or cognitive activity projected to solve problems and closely related to make conclusion, which characterizes mathematical activity.

Analogy, according to Indonesian Dictionary, is an equation or a rapprochement between two objects or two different things (Setiawan, 2010). Woo et al (2007, p. 145) explains that reasoning is classified into three types: induction, analogy, and imagery. These three forms of reasoning represent mathematical reasoning, particularly in the field of geometry (Lee et al, 2007, p. 145). The types of reasoning are also grouped into three categories: induction, deduction and analogy (Mofidi & Amiripour, 2012, p. 2917). Pertaining to the above explanation, analogical reasoning, therefore, is clearly a part of mathematical reasoning.

Analogical reasoning is the process of obtaining and adapting the already well-learned ways of solving problems to resolve new problems (Vybihal, 1989, p. 1245). Analogical reasoning, hence, maps out problem solving strategies on the source domain and relates them to the new target domain. Analogical reasoning, according to Gust and Kunhnberger (2006, p. 1422), is an important ability of human cognition as it can be used to explain many aspects of humans' cognitive creativity, productivity, and adaptation. Moreover, analogical reasoning, in a broad sense, can be defined as comparing two objects by highlighting their similarities (Antal, 2004, p. 4). In a narrower definition, it reasons out the elements of similarity between two domains and attempts to explain their relationship. This aspect of similarity and relationship can deal with terms, shapes, characters, stories, systems, and problems. Analogical reasoning in this study, therefore, relates to decision making process based on the use of reasoning schemata identified in the source domain and applied to the target domain.

Components of Analogical Reasoning

Sternberg (1977, p. 355) spells out the components of analogical reasoning as follows. a) Encoding is a process when the reasoner identifies and encodes the terms of the analogy found in the source domain. b) Inferring is a process when the reasoner examines similar qualities in the source domain and infers the relation between them. c) Mapping is a process when the reasoner maps the relation of identical terms in the source domain and in the target domain and infers the relation between them. d) Applying is a process when the reasoner chooses a relation analogous to the inferred one by applying the closest one to the target domain.

Ruppert (2013, p. 2), moreover, suggests four processes of analogical reasoning, namely, structuring, mapping, applying and verifying, description of which is spelled out as follows. a) Structuring is a stage to identify mathematical objects by encoding the object attributes in the source of analogical reasoning and to infer all possible relations involved. b) Mapping is a stage to examine the identical relation of the inferred one in the source domain and build analogous conclusion based on the similar characteristics which then are mapped and related to the target domain. c) Applying is a stage to apply the inferred relations in the source target to solve problems in the target source. d) Verifying is a stage to evaluate the applied strategies in the problem-solving activities to verify its merit by re-examining the relation between the two domains. The components of analogical reasoning proposed by Ruppert (2013) are mainly employed in this study.

Analogical Reasoning Skills

Reasoning is one of basic competence of learning mathematics, in addition to understanding, communication, and problem solving. The Education National Standard Board (BSNP) (2006, p. 140) stipulates 5 principle competencies to be achieved by students in mathematics, namely, (a) understanding the concepts of mathematics, explaining the relationship between the concepts, and applying the concepts or algorithms with flexibility, accuracy, efficiency and precision in the problem-solving activities, (b) using reasoning on patterns and properties, employing mathematical manipulation in making generalization, compiling evidence, or explaining ideas and statements of mathematics, (c) solving mathematical problems that include the ability to understand the problems, design a mathematical model, complete the model, and interpret the obtained solution, (d) communicating ideas with symbols, tables, diagrams or other media to clarify the situation or problem, and (e) taking a positive and appreciative attitude to mathematics reflected in the students' curiosity, attention and interest which are supposed to build their confidence and tenacity in dealing with problem-solving activities.

Reasoning and problem solving are very essential parts in learning mathematics for the foundation of mathematics is formed and developed through a process of reasoning and problem solving. To foster the students' reasoning and problem-solving skill in mathematical activities, it is therefore imperative for the teacher to have an adequate ability to sustain the ability to reason and solve problems., particularly mathematical problems. Basically, to solve any mathematical problems, reasoning ability is essentially required. Through reasoning, the students are expected to see that mathematics is governed by reason and logic. Thus, the students feel confident that mathematics can be understood, reasoned out, proven, and evaluated. In so doing, they have to learn the ability to reason.

Reasoning, according to Herdian (2010), comprises several concepts; a) it is commonly associated with the ability to find solutions or solve problems, b) it is also associated with the ability to draw a conclusion as in the syllogism corresponding to the ability to assess the implications of an argument, and c) it is the ability to see relationships between objects or ideas, and then employ that inferred relation to discover new objects or ideas. In a nutshell, analogical reasoning is the ability to discover relationships between two domains, the inference of which is devoted to solve problems or develop new ideas. Indicators used to identify whether students have successfully achieved criteria for mathematical reasoning (Table 1).

The analogical reasoning and its indicators proposed by Sumarno (2015) above are to be further described as follows. First, encoding constitutes discovering relation to make an analogy and a generalization, and to propose and test a conjecture. Secondly, inferring relates to drawing inferences from the given propositions. In addition, pertaining to the Directorate General of Primary and Secondary Education, Department of National Education (in Yulia, 2012) and Sudjadi (2010), both come to a similar statement that encoding includes discovering patterns or attributes in the mathematical problems to make generalizations. They also come to a similar statement as of Sumarno's (2015) pertaining to inferring. Finally, verifying relates to examining the validity of an argument.

Table 1. Indicators of Mathematical Reasoning Skill

Sumarno (2005)	Regulation of the Directorate General, Primary and Secondary Education, Department of National Education, No 506/C/Kep/PP/2004 (in Yulia, 2012)	Sudjadi (2011)
a. Drawing logical conclusions.	a. Proposing hypothesis.	a. Presenting information using verbal and written forms, symbols, diagrams and etc.
b. Presenting findings using symbols, facts, attributes, logical relation.	b. Employing mathematical manipulation.	b. Proposing hypothesis.
c. Predicting answers and its process.	c. Drawing conclusions, providing evidence, giving reasons or evidence to verify the inferred solution.	c. Employing mathematical manipulation.
d. Employing analogous patterns to analyze, generalize, propose and test a conjecture.	d. Drawing conclusions from the given propositions.	d. Drawing conclusions.
e. Providing instances.	e. Verifying the validity of an argument.	e. Gathering evidence, giving reasons to verify the inferred solution.
f. Making inferences, verifying the validity of an argument and making a valid argument.	f. Discovering patterns from mathematical problems to make generalizations.	f. Drawing conclusions from the given propositions.
g. Developing evidence either directly or indirectly and inductively.		g. Verify the validity of an argument.
		h. Discovering patterns from mathematical problems to make generalizations.

METHOD

This study is referred as qualitative as the findings will describe the analogical reasoning of students exposed to algebraic problems. This research was conducted in 4 high schools in Surabaya; SMAN 15, SMAN 21, SMA Kemala Bhayangkari 1, and SMA Al-Falah, respectively. There were 42 students, all of which are 12 graders, opted for the study as research subjects. These selected students are those with high mathematical skills and good communicative skills, information of which was elicited on the recommendation of the teacher.

The researcher gathered the data from worksheets administering mathematical problems to the students. In addition to that, the results of think aloud process, transcribed interviews and video recording of the students doing the test served as the data for the study as well. *Think Aloud* method was employed to govern the process of gathering data. Each student was given mathematical problems to be solved. In this problem-solving activity, the researcher asked the student to verbalize his thoughts while the student was trying to solve the problem. The utterances were recorded and any observed behavior was noted. As one student finished this process, the same stages were projected to another student.

The data were analyzed qualitatively, particularly through an interactive analysis method. In the study, each unit of analyses was focused in each of four proposed categories: structuring, mapping, applying and verifying, respectively. The verbal and written data elicited from the students were then categorized and coded.

RESULTS

In this study, an instrument was designed to develop the students' analogical reasoning through algebraic problems. The worksheet administered to the students is presented in Figure 1.

With regard to the above research instrument, it is aimed to drive the students to investigate the contexts as the data are partially given. In such a close-ended algebraic problem, each constanta in each equation is known already. In the research instrument above, there

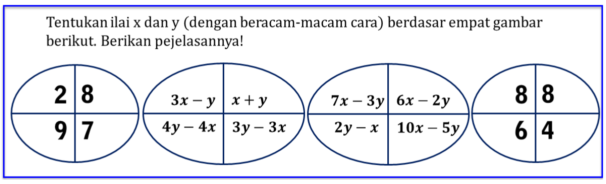

Figure 1. Research Instrument

are various values of a constanta and such a design, therefore, compels the students to identify and discover certain patterns or relations among the circles and finally make inferences.

The findings revealed that there were 21 students who employed analogical reasoning and 21 students who did not use the reasoning. The former comprised two groups; 11 students were referred as internal structuring and 10 students were referred as connective external structuring. Constant comparative method was then employed in which two subjects were selected from the two groups to be further analyzed.

The students who employed analogical reasoning, categorization of which was seen from two indicators they arrived at, were placed in the first group. The two indicators are (1) to find analogous patterns to analyze, generalize, propose and test a conjecture, and (2) to draw inferences from the given situations. The subjects that belong to this group are henceforward referred as S1 and S2. Since the two subjects employed the same characteristics of reasoning, a description of S1' reasoning alone was deemed to be sufficient.

With regard to S1, it was found that S1 associated the numbers in the first circle with addition and S1 thus came up with 26. Moreover, S1 found that the addition of all numbers in the fourth circle made 26 as well. Based on this finding, S1 performed structuring the problem. As S1 found a relation between the two circle through the addition, S1 performed encoding. In other words, S1 had discovered a code highlighting the same characteristics in the two domains. The process of encoding the relation in the two domains was based on S1' statement as follows.

S1: *So, the second strategy is by adding all equations in the circles…*

The process of structuring in S1 analogical reasoning can be represented in Figure 2.

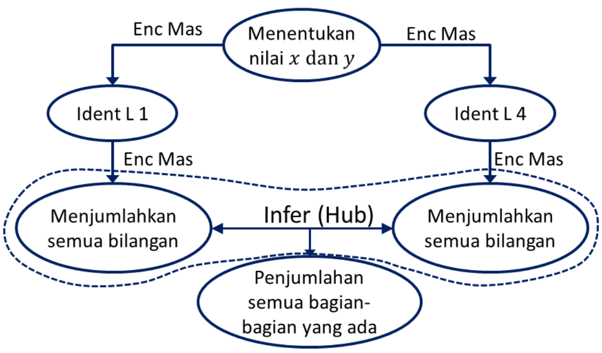

Figure 2. The S1' process of *Encoding and Inferring* in the Source Domain

Indeed, the students, whose analogical reasoning met 3 indicators, were placed in the second group. The 3 indicators are (1) to discover patterns from mathematical problems to make generalizations, (2) to draw inferences, and (3) to verify the validity of the argument. The subjects that belong to this internal structuring are henceforward referred as S3 and S4. As the two subjects employed the same characteristics of reasoning, a description of S3' reasoning alone was deemed to be sufficient.

As S3 faced the algebraic problem, S3 had been able to discover a shared characteristic among the four circles; S3 grasped the relations, with regard to corresponding variables. As S3 was identifying the problem, S3 connected the numbers and variables in all circles. It can be concluded that S3 displayed the three stages of analogical reasoning, as evidenced by how she attempted to connect each characteristic in each image. It related to her findings on the addition of variables in the third and fourth circle would be equivalent to the variables in the first and the fourth circle. This marked her process of encoding and this process led to inferring in which S3 had discovered the relation between mathematical system in the source domain and in the target domain. This process can be seen in S3' statement below.

S3: *So, you can try this (pointing the item)..take, for example, this one (pointing the up and left part of the second image) and this one (pointing the up-left part of the third image) if you add them, you come up with the same number in this (pointing the up-left part of the first image) and this one (pointing the up-left part of the fourth image) you add them..*

S3 doubted the value of x and y that she had found so that she verified her answer by trying to find another relationship in the algebraic problem. She then connected the left-below part and the right-below part. S3 verified whether the addition of the left-below parts of the second and the third circle would make the same number as of which the left-below part of the first and the fourth circle. This attempt made a third two-variable linear equation. Furthermore, the same strategy was applied to the right-below part of the four circles. This made a fourth two-variable linear equation. With regard to the above description, it showed how S3 managed to verify the validity of her answer. Pertaining to that, it can be seen from the statement expressed by S3 below.

S3: *(and S3 was pondering over her answer in silence for a moment and trying to find another equation remaining, the left-below and the right-below part of each image). (Writing down the third equation and pointing the left-below part of the third and the fourth circle) the addition of* 4y-4x and 2y-x *make the same number like (adding number 9 in the first circle and number 6 in the fourth circle) fifteen…*6y-5x *makes fifteen…(writing down the fourth equation and pointing the right-below part of the second circle) the addition of* 3y-3x *and* 10x-5y *makes..(adding number 7 in the first circle and number 4 in the fourth circle) eleven..(she is pausing for a moment)* 7x *minus* 2y *makes eleven…*

The excerpt of the interview with S3, with regard to the process of verifying, is presented below.

P: *Could you explain to me how you solved the problem?*

S3: *So, I added* x-y *and* 7x-3 *(pointing the up and left part of the second and the third circle). After that, it's equivalent to the addition of two and eight (pointing number 2 in the first circle and number 8 in the fourth circle). So, you added all in the same part…this one and that one (pointing another part of each image) and then it's... It's subtracted and eliminated. Done…*

Based on the process of verifying, S3 came up with a new finding: x = 3 and y = 5. In the worksheet, S3 initially did not verify the validity of the answer. However, through the interview, S3 showed confidence that S3 gave a correct solution. This notion corresponds to the below excerpt of the interview.

P: *Are you sure with your answer?*

S3: *Yes.*

P: *How did you know that your answer is correct?*

S3: *Well, I had put the x and y in all equations provided and the results are correct.*

With regard to S3' process of verifying, it is presented in Figure 3.

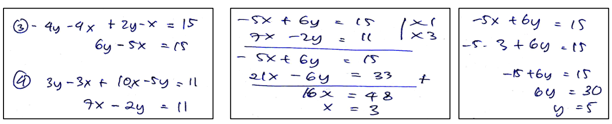

Figure 3. S3' Exploration on the Process of Verifying

The structure of S3' analogical reasoning as she solved the algebra problems is represented in Figure 4.

With regard to the process of reasoning, S3 had been familiar with the problem faced, and S3 also had been able to discover some relations among the problem and the problem-solving strategy. The analysis of the think aloud process and interviews showed that S3 had displayed the process of encoding, inferring and verifying. The students, therefore, had successfully assessed and transferred the mathematical options from the base to the target to solve the problem.

DISCUSSION

This study described a way of developing students' analogical reasoning, the results of which attested the findings of the previous study. The findings on the students' analogical reasoning closely correspond to components of analogical reasoning proposed by Rupert (2013). With regard to the above statement, it is concluded that structuring components in Rupert (2013) share similar characteristics with those of mathematical reasoning: (1) they constitute two similar indicators and (2) they share three similar indicators.

Moreover, the students, whose analogical reasoning met only two indicators, were classified into the first group. The two indicators are (1) to find analogous patterns to analyze, generalize, propose and test a conjecture, and (2) to draw inferences from the given situations. Pertaining to the process of reasoning, the subjects in this group had discovered the problem they faced, some relations among the problem and the problem-solving strategy. Based on the results of think aloud process and interviews, the subjects had performed the process of encoding and inferring. However, this analogical reasoning cannot be deemed to be complete due to the absence of verifying process.

Indeed, the students, whose analogical reasoning met 3 indicators, were placed in the second group. The 3 indicators are (1) to discover patterns from mathematical problems to make generalizations, (2) to draw inferences, and (3) to verify the validity of the argument. With regard to the process of reasoning, the subjects in this group appeared to have been familiar with the problem they faced, and to have discovered some relations among the problem and the problem-solving strategy. The analysis of the think aloud process and interviews showed that the students had displayed the process of encoding, inferring and verifying. The students, therefore, had successfully assessed and

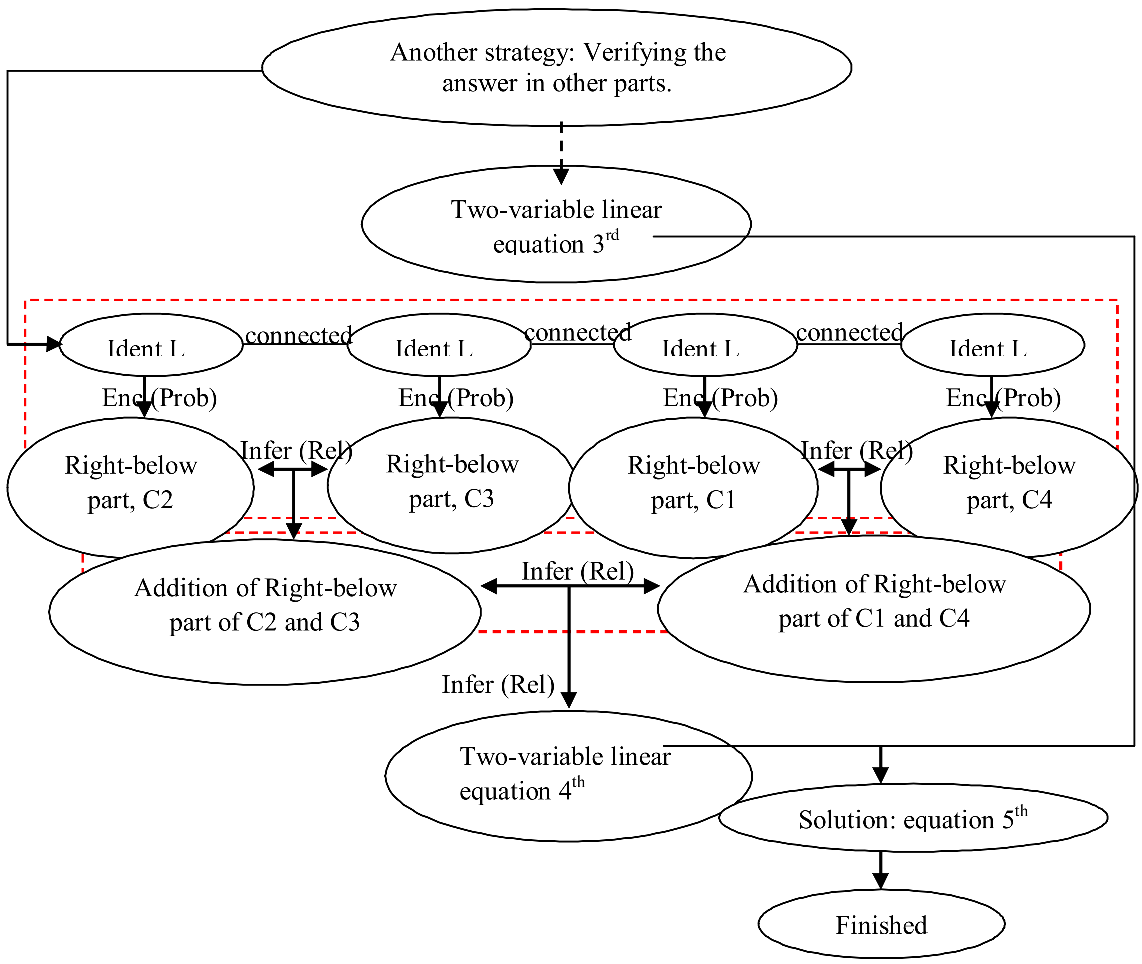

Figure 4. The Structure of S3' Analogical Reasoning after Verifying

Notes: Enc (Prob) = Encoding the problem under investigation, Infer (Rel) = Inferring the relation of the problems

transferred the mathematical options from the base to the target so that the problems can be solved by analogical reasoning. Hence, it can be concluded that the subjects could achieve the complete stages of analogical reasoning.

CONCLUSIONS

Based on the above discussion, it is plausible to conclude that developing analogical reasoning is of great importance for students to face the AEC. Though the definitions of analogical reasoning might vary, it should be viewed objectively and positively as a way to provide a wider spectrum of understanding. With regard to its application in teaching and learning process, this reasoning should be adapted to meet the characteristics of each subject. Particularly in mathematics, the use of analogical reasoning has likely gained considerable attention and even has been a new perspective.

It is also concluded that structuring components in Rupert (2013) share similar characteristics with those of mathematical reasoning. These similarities include 3 principle indicators, namely, (1) discovering patterns from mathematical problems to make generalizations, (2) drawing inferences, and (3) verifying the validity of the argument.

Adhering to the indicators governing the categorization of analogical reasoning in mathematics, this research yield two groups; the former meet only two indicators and the latter three indicators of reasoning abilities. In this study, developing the students' analogical reasoning is limited to mathematical problems, particularly through algebraic problems. Therefore, it is suggested that analogical reasoning is to be developed and projected for other mathematical problems. Promoting the analogical reasoning in other fields other than mathematics is also of great importance.

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