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Improving Level of Algebraic Reasoning for Junior High School Students using Metacognitive Training

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Abstract

Mathematics as one of the sciences that discusses abstract concepts, certainly requires a good reasoning process in understanding it. One of reasoning in mathematics is algebraic reasoning, which used as a foundation for algebraic thinking. As one of the curriculum competences, the algebraic reasoning from Junior High School students is still in the low level. This article discusses how the initial conditions of algebraic reasoning level from Junior High School students, and how to improve it. One of ways that can be done is using metacognitive training. Metacognitive training gives freedom to students to solve the problems by themselves with some integration guidance. It is hoped that students will be able to guide themselves through the process of algebraic reasoning level improvement. There are some important things that should be considered to get the optimum result in improvement process. And also, the main discussion is how the metacognitive training can improve the algebraic reasoning level of Junior High School students.

Keywords:

Algebraic Reasoning, Level of Algebraic Reasoning, Metacognitive Training

1. Introduction

In the industrial revolution 4.0, it is important to develop various competencies that support the improvement of human resource competitiveness. One of the competencies needed is reasoning ability as the basis of the thinking process. The ability of reasoning was developed according to their respective fields of study, and one of them is mathematics. As the knowledge that discusses various abstract concepts, mathematics requires good reasoning abilities. One of the reasoning that become an important object in mathematics is algebraic reasoning which become the basis for thinking algebraically in solving various daily problems mathematically.

In school of mathematics, there are a lot of branch that should be learned by students. Algebra is one of them. As the gateway to higher mathematics, algebra is also a tool for solving complex mathematical problems as a result of generalization of simple problems and making relations of various mathematical concepts. Thus, it is important to have a good ability in algebraic reasoning as a base for algebraic thinking in solving problems.

According to *Trends in International Mathematics and Science Study* (TIMSS) data, Indonesian students' mathematical grades ranks 36th out of 49 participating countries in 2011 and ranks 46th out of 51 participating countries in 2015. It means there are a lot of problems with the student capability in understanding mathematics well. In curriculum, the government has revised the KTSP to be 2013 Curriculum, but it does not impact significantly to the problem. In addition, TIMSS measures the level at which algebra is introduced to students. So, it shows that the low ranking of Indonesian mathematics due to the low ability of students' algebra. So it is necessary to know how algebra learning is carried out so that it gives an impact on improving the level of students 'algebraic reasoning which encourages high mastery of students' algebraic concepts.

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The authors use the study of literature methods in this article. Based on Embun (in Melfianora, 2019) research that is only based on written article both published and not yet published included in the study of literature. The authors use various scientific journal references to determine the role of metacognitive training in improving the level of algebraic reasoning for junior high school students.

We already know that algebra can investigate and communicate most of mathematics problem. Algebra is a way of thinking, a collection of concepts, and skills that enable students to generalize, model, and analyse mathematical situations. There are four goals related to algebra in the Principles and Standards of School Mathematics: (1) understand the patterns, the relationships, and the functions, (2) representing and analysing mathematical situations and structures by using algebraic symbols, (3) Using mathematical models to represent and understand quantitative relationships and (4) analysing the changing in various contexts (NCTM in Rosita, 2018).

Algebra can be seen as general arithmetic and also to study functions and relationships among other variables (Rosita, 2018). Algebra in particular has a lot to do with other fields of study so that create the parts of algebra itself such as concrete algebra, linear algebra, general algebra and computing algebra. Meanwhile, according to James, algebraic reasoning is the generalization of the mathematical idea of a particular thing through argumentation, and states formally according to the age of the pupils (Indraswari, 2018). Kaput states that students who develop concrete algebraic reasoning can generalize specific situations to mathematical ideas in increasingly formal ways from a specific situation and express these generalized ideas through discourse with others (Yujin Lee, 2018). Friel also states that algebraic reasoning, which was generalized from the particular situations, can help students "to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and analyze change in various contexts" (Yujin Lee, 2018).

While metacognitive training, according to Kramarski & Mevarech, is the application of the concept of metacognition as a method for teaching practically. This training includes small-scale group activities for students to ask and answer their own questions. The question that arises is said to be a metacognitive question which is handled by itself from questions that arise naturally and relate to new and previous knowledge and the use of appropriate strategies to solve problems (Yujin Lee, 2018). Zimmerman (in Yujin Lee, 2018) added that through this strategy, deep learning can be developed by students. In addition, students will also be actively involved in cognitive processes and have a better mathematical understanding which is increasing algebraic.

This article will describe how to improve algebraic reasoning level from Indonesian students that still in the low level by metacognitive training. This article will give some reason why we should pick the metacognitive training to help us in the problem and how metacognitive training can affected in the process to improve algebraic reasoning of students that still in the low level. Last but not least, this article will also discuss about the metacognitive impact in the learning briefly and how is the condition of students algebraic reasoning level.

2. Discussion

Watson and Ameron (in Rosita, 2018) suggest to look algebra widely, that is to look algebra as: (1) general arithmetic, (2) problem solving tools, (3) relationship studies, and (4) structure studies. As for the gateway to mathematics and high-level mathematical thinking, algebraic reasoning take a part as the basis. Essentially, algebraic reasoning is the basis of human interaction and interpretation of the world. The pattern finding, the recognizing important aspects of patterns, and the generalizing of simple problems towards more complex ones, are important parts of algebraic reasoning. Clearly the algebraic reasoning ability is an important thing that is owned by every human being and must be continued to be developed. Why is this important? According to Dudley (in Johnson, 2012), algebraic reasoning is a transfer, that the type of reasoning required by algebra will improve reasoning skills and that reasoning skills will be transferred to other fields of thinking and understanding, which could be different.

2.1. Algebraic Reasoning in Junior High School

Algebraic reasoning is interpreted as a process of generalizing student experience into mathematical ideas and connecting them in formal statements in school mathematics. Generalization here is an activity to find the patterns of certain mathematical problems or contextual situations, making connections through formal symbolic representation and manipulation.

Based on NCTM indicators, the following are leveling for algebraic reasoning: (1) understanding patterns, (2) making algebraic symbols, (3) making mathematical models, and (4) analyzing change. Meanwhile, according to Godino et al (2016), there are seven levels of algebraic thinking in primary and secondary education: (1) level 0, operations with certain objects using natural language, numerical, iconic, and gesture, (2) level 1, starting with "generic numbers", property of algebraic N structures and algebraic equivalence (equivalence), that is, relational thinking, (3) level 2, starting with alphanumeric representations of functions and equations and simplifying expressions, (4) levels 3, starting with unknown treatments and variables using structural properties (invalidation, substitution, etc.) as well as algebraic and functional modeling, (5) level 4, starting with the use of parameters in the functions and coefficients of variables, that is, with the expression of equations and functions , which is an intensive second order object, (6) level 5, starting with the unknown combined treatment, variables and parameters as well as the solution structure that arises from the parameters treatment, and (7) level 6, starting with the study of the algebraic structure itself , the definition and the structural properties (NCTM, 2000).

Research on algebraic reasoning mostly proves that algebra is difficult to be understood. As in the introduction, the results of TIMSS in recent years indicate that students' algebraic understanding, especially in junior high schools, is still lacking. The struggle encountered by many students in junior high school when studying algebra is mainly due to the imperfect introduction of algebra. Arithmetic and algebra are considered as two different disciplines. Arithmetic is related to the elementary school syllabus while algebra is associated with the junior high school syllabus. Elementary school students associate with the arithmetic questions from the first year and as soon as they enter junior high school, they are confronted with algebraic variables, functions and expressions without any recognition.

As the evidence, in the 2013 curriculum, algebraic expressions were introduced in chapter three of VII grade of junior high school and introduced after the arithmetic without a clear transition. When students meet algebra first in abstract form, causes many difficulties for students who are only accustomed to concrete reasons throughout the elementary school year. One of the main problems in algebra is the difficulty of students in understanding basic algebraic concepts, that is the concept of variables. If likely given an equation:

$$2x + 1 = 3 \ \ldots (1)$$

students are only taught to find the value of x using the procedure by bringing 1 to the right side, subtracting from 3 and divided by 2. The primary concern here is whether students know why they are required to do it? What is meant by equation 1? How was it revealed? What does x mean? Finally, do they know how to interpret the answers they find? In problem solving, algebraic reasoning processes need to get the teacher's attention to help students develop algebraic reasoning abilities. However, it does not mean that students simply memorize formulas and apply them in questions without knowing the underlying reasons and concepts. Algebra, and especially symbolic manipulation, is understood as a collection not related to "computational rules", to be memorized and applied. Similarly for functions, students barely know the concept behind $f(x)$

Students who develop algebraic reasoning from concrete reasoning can generalize certain situations related to mathematical ideas in an increasingly formal way and express general ideas through discourse with other people. Invention from the previous studies show that many students are not involved in age-appropriate algebraic reasoning and struggle when mathematical problems require them to move from arithmetic to algebraic reasoning. Extending their reasons from static situations to dynamic situations, from concrete objects to formal symbols, and from special thinking to generalization is a difficult process for many students. And that requires support from various aspects.

The conditions are not much different when the teacher will train students by giving all possible questions that can be asked in the exam. As a result of such activities, students will achieve exceptional value in examinations without developing a process of reasoning and thinking.

A student's algebraic thinking is very dependent on the experience they get in the classroom. Students do not develop all their algebraic thinking and abilities by only memorizing concepts and carrying out routine procedures at school. Because this will create a low level of algebraic reasoning. It may not be possible to reach level 4 alone. Teaching methods and class activities also play an important role. In addition, teaching methods and classroom activities cannot be improved without systematic evaluation of students' algebraic thinking and cognitive identification for the variables that influence it. Thus, this separation between algebra and arithmetic causes a cognitive gap between the two, which then makes learning algebra more difficult for students in subsequent years. The National Council of Mathematics Teachers (NCTM, 2000) has also recognized the importance of growing algebraic reasoning from the ground up as a basis for algebraic thinking. However, there are technical things that can be improved to make a good impact on increasing the level of student algebraic reasoning, namely the learning method.

2.2. Metacognitive Training and its Impact in Learning

Cunningham (2018) writes that metacognition is often used as a vague term that refers to "thinking about thinking", but this description obscures its function and usefulness in learning. In general, but more specifically, metacognition involves our knowledge and regulation of our thinking processes. Even though everyone is metacognitively active to some degree, we all have room to grow and benefit from improving our metacognitive skills.

In particular, many students who survive dominantly use a surface approach to learning, such as practice and memorization, but can benefit greatly from a more elaborative and organizational approach related to deeper learning. In this case, metacognition can be a solution. In learning, metacognition includes students' thought processes and beliefs that enable them to organize their own learning activities. During the metacognitive process, both cognitive knowledge and skills are planned, monitored, analyzed, evaluated, and reflected by students based on their own goals.

Helms-Lorenz & Jacobse (in Yujin Lee, 2018) argue that using this metacognitive process has a positive impact on student academic achievement. In addition, this process encourages students' willingness to learn what is associated with increased self-efficacy. The use of metacognitive training gives positive results for students.

Metacognition involves the interaction of the knowledge cycle and regulation of human thought processes. Knowledge about cognition consists of knowing about people, tasks, and strategies. Cognition regulation is to put our knowledge into action through planning, monitoring, controlling, and evaluating activities. Knowledge of people is knowing about how people process information in general and how you process information specifically. Knowledge of the task is to know the cognitive demands of various cognitive tasks. Knowledge about strategy is knowing various ways of thinking or engaging with different tasks. Planning is to take stock of cognitive tasks, to set goals and choose initial strategies in a balanced way by knowing how you process information. Monitoring ie tracking progress on a task while doing a task. Controlling is taking action in response to monitoring assessments. Evaluating is assessing how cognitive tasks work after completing tasks, building your cognitive knowledge.

2.3. Metacognitive Training dan Improving Level of Algebraic Reasoning

Recently, metacognition received more attention related to its role in improving students' algebraic reasoning in school mathematics. Although algebraic reasoning has been considered as an important factor influencing students' mathematical performance, many students struggle to establish concrete algebraic reasoning. Metacognitive training has been carried out considered one of the effective methods for developing students' algebraic reasoning. Based on Yujin Lee (2018) metacognitive training has a significant positive impact on students' algebraic reasoning.

Metacognitive training is one of the practical teaching methods in which the concept of metacognition is adopted. Metacognitive training provides small group activities for students to ask and answer questions themselves. These self-addressed metacognitive questions consist mainly of questions that naturally arise and which relate to the relationship between prior knowledge and new knowledge, and the use of appropriate problem solving strategies. The metacognitive training strategy encourages students to make them exert extra effort at the beginning, and prolonged training to ensure the smooth and application of metacognitive activities. Through the use of this strategy, students can develop deep

learning, active cognitive processing, and better mathematical understanding, which will have an impact on improving algebraic reasoning. For this reason, metacognitive training should be considered an effective method for improving students' algebraic reasoning.

Because of the high hopes of being able to increase students' algebraic reasoning levels, metacognitive training needs to be given special attention. The part of good metacognitive training activities, starting from the overall design. At least make modules that are accessible, easy to use, and take limited class time. For example, module 1 discusses the introduction of a metacognitive framework and argues about the importance of metacognitive knowledge and regulation. Module 2 focuses on metacognitive knowledge about self, tasks, and strategies. Module 3 introduces students to the idea of assessing learning experiences to determine what works and what doesn't. Module 4 introduces students to the idea of focusing on tasks that are part of a large project and part of an important goal rather than tasks that are distracting. Module 5 introduces students to monitor and control their learning during the learning experience, operationalized through the experiential learning cycle. Module 6 serves as a summary that asks students to reflect on topics from previous weeks and think about how they can apply what they have learned going forward (Cunningham, 2018).

Overall, illustration of the integration in early algebraic reasoning requires more than the introduction of algebraic concepts. It was necessary for the teacher to reflect on both the planning and implementation of suitable tasks, and also the importance of development of the classroom community and facilitating the growth of classroom practices and mathematical practices that supported collective student participation and engagement with algebraic reasoning. Last but not least, a good capability in assessing students performance in algebraic reasoning also improve the level of algebraic reasoning (Hunter, 2015).

3. Conclusion

The reason of junior high school students' algebraic reasoning is still low, mostly due to imperfect introduction of algebra. Both in terms of material that is not smoothly transitioned from arithmetic, the separation of the focus of mathematics learning in elementary and junior high schools, as well as the unpreparedness of students who are immediately introduced to abstract algebraic forms. In fact, most students are familiar with the concrete reasoning they have learned since elementary school. This is then exacerbated by the teacher learning method that is focused on how students pass the exam by giving all possible forms of questions. Class activities in algebra learning that do not support also become a barrier to the process of increasing the level of reasoning of junior high school student algebra.

The first solution offered is to provide algebraic teaching early. However, this will require a long time and process. Because earlier teaching requires better preparedness in terms of facilities and infrastructure, one of which is curriculum, so to be more concrete, the search for appropriate teaching methods is used to increase the level of reasoning of junior high school students. The teaching method in question must have a positive impact on increasing the level of student algebraic reasoning.

Metacognitive training is considered to have a good impact on learning. Judging from some previous studies, metacognitive training has a positive impact on increasing the level of student algebraic reasoning. Proven in 18 of 22 studies related to this a positive impact. However, several things need to be considered in order to increase the level of algebraic reasoning to be optimum, namely planning measurable activities, organized implementation, and assessment in accordance with the objectives of increasing the level of algebraic reasoning itself.

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