An analysis on generational, transformational, global meta-level algebraic thinking ability in junior high school students

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Abstract. The purpose of this study was to determine the effect of students' generational abilities on students' global meta-level abilities, to determine the effect of students' transformational abilities on students' global meta-level abilities, as well as the influence of students' generational and transformational abilities on global meta-level abilities. This type of research is quantitative research with population eighth grade students of Semarang City Junior High School. A sample of 124 students obtained by stratified random sampling technique. Data is processed by correlation and regression tests, as well as the presentation of data in the form of diagrams. The results showed that students' generational ability had a positive effect on global meta-level ability, students' transformational abilities had a positive effect on global meta-level abilities, and together generational and transformational abilities had a positive effect on global meta-level abilities.

1. Introduction
Mathematics is one of the subjects taught by almost all levels of education. With mathematics students are invited to think and reason, both to solve problems related to everyday life and the mathematical problems themselves.

One branch in mathematics is algebra. According to Ulusoy, Algebra is a branch of mathematics that studies about symbol manipulation and solving equations” how to express something general and pattern” [1]. One of the main strengths of algebra is as a tool for generalizing and solving various problems.

Understanding the basic concepts of algebra is very important because almost all mathematics field requires algebra as problem solving [2]. Thus, algebra is a very important material to be mastered by students, because implicitly and explicitly algebra is used in daily life activities. This is also revealed explains that Algebra is an important aspect mastered by students because algebra determines the success of student achievement in high school, and most mathematics educators allow for the inclusion of algebra-based topics in elementary and secondary mathematics classes [3].

Algebra is a development of arithmetic. Learning algebra after arithmetic means building a different way of thinking. Arithmetic has been assumed to be a prerequisite for the emergence and development of algebraic thinking [4]. Algebra and arithmetic are useful for solving a problem, but the solution is different, so algebra cannot be considered as a continuation of arithmetic. Arithmetic reflects abilities with four arithmetic operations, and can be seen as procedural ability that primarily require algorithmic solution strategies [5]. Unlike arithmetic, the main purpose of algebra is not to do numerical calculations, but to provide the operative language to represent, analyze and manipulate relationships contained in numbers and letters.
Usually students only focus on calculations. During this time, students do well in arithmetic. But experience difficulties in matters related to algebra. Students are easier to memorize facts and algorithms to solve thinking problems at low levels, while algebra uses higher levels of thinking.

TIMSS (Trends in International Mathematics and Science Study) is a survey institution that assesses the skills of fourth and eighth grade students in the fields of mathematics and science. Indonesia followed TIMSS for eighth grade students. There are four dimensions of mathematical content in eighth grade namely numbers, algebra, geometry, and data and opportunities. Based on data from TIMSS results in 2011 shows that the average ability of Indonesian students in each dimension of content is still far below that of Singapore, Republic of Korea, Japan, Malaysia and Thailand [6]. The lowest average percentage achieved by Indonesian students is on the dimensions of algebraic content of 22%. This shows that the algebraic abilities of Indonesian students are still low. The reason for the weakness of Indonesian students in algebra is thought to be due to the lack of ability to apply knowledge in linking the concepts of numbers and algebra, not having the ability to make mathematical models and generalize algebra.

In the teaching and learning process that involves the basic concepts of algebra, there is a thinking process that must be mastered by students that is algebraic thinking. The term algebraic thinking appears as a representation of activities in learning things related to algebra [7]. Algebraic thinking is thinking that involves the development of mathematical reasoning by building meaning for symbols and algebraic operations. The most important aspect of algebraic thinking is the ability to link and generalize mathematical problems using mathematical models and algebraic symbols, so that they can generalize the solutions they get [8].

The process of understanding in algebra includes understanding algebraic equations as generalizations of arithmetic, in algebraic operations is a continuation of arithmetic [9]. Algebraic understanding is the ability to recognize functional relationships between independent variables and dependent variables, interpret and distinguish between differences from algebraic concepts. This is realized by the ability to read, write, and manipulate algebraic numbers and symbols, symbols used in formulas, equations and inequalities.

Some algebraic understandings planned in the classroom, among others: arithmetic generalizations, functional relationships, properties of numbers and operations [10]. Whereas according to Kieran in thinking algebra includes generational, transformational, and meta-global levels. These three abilities are very important in the ability to think algebra [7]. Generational, transformational, and meta-global levels are the most important part of algebra learning [11]. Thus, analysing the three algebraic thinking skills, namely generational, transformational, and meta-global levels in school learning is very useful in determining the improvement of school algebra learning.

Algebra research has been carried out illustrating that a class taught by incorporating transformational activities can have a good influence on algebraic expression [12]. Other research results show that if the algebra mastery of Norwegian high school students is an important aspect, it is necessary to include more transformational activities in learning mathematics [13]. Whereas Girit & Akyüz argues that focusing algebraic thinking in the early class and relating it to students' arithmetic knowledge is important [14]. Research on Algebraic thinking is an issue that has attracted many researchers [15].

Based on the description above, the formulation of the problem in this study is (1) whether there is influence of the ability of the generational students with the global meta-level abilities of students; (2) is there any influence of transformational abilities of students with global meta-level abilities of students. (3) whether there is influence of students' generational and transformational abilities on global meta-level abilities of students.

The purpose of this study is to determine the effect of students' generational abilities on students' global meta-level abilities, influences transformational ability of students towards students' global meta-level abilities, as well as the influence of students' generational and transformational abilities on global meta-level abilities.

2. Method
This research is a quantitative research that analyzes the generational, transformational, and global meta-level of students. The research population was the eighth grade students of Semarang City State Middle
School in 2018/2019. With stratified random sampling technique selected SMP 3 as a sample of favorite category junior high school, SMP 6 as a sample of middle category junior high school, and SMP 41 as a sample of lower category junior high school as a total of 123 students as a sample. Data collection methods used in this study are tests of students' algebraic thinking skills. Data analysis using simple regression analysis, multiple regression and correlation, and presentation of data in the form of diagrams. Generational, transformational, and global meta-level algebraic thinking indicators are taken from Kieran [7]. The test instrument was validated by a mathematics lecturer and one junior high school mathematics teacher. The test is then tested to find out the validity, reliability. In this study classifying algebraic thinking skills in 3 levels, the low group with the value \( N \leq N \leq \bar{x} - SD \) the medium group with the values \( \bar{x} - SD < N \leq \bar{x} + SD \) and high groups with the value of \( N > \bar{x} + SD \).

3. Results and Discussion
In this study the effect of students 'generational abilities on students' transformational abilities, the effect of transformational abilities on students on the global meta-level abilities of students, and the influence of students 'generational and transformational abilities on students' global meta-level ability, so that the dependent variable is global meta-level abilities, then this data is tested for normality. With the help of SPSS test one sample KS test obtained \( \text{sig} = 0.310 > 0.05 \) so that global meta-level capability data is normally distributed.

3.1. First Results
The data used in this test is the test result data generational think algebra capabilities students represented by \( X_1 \) and the global meta-level ability of students represented by \( Y \). Testing includes determining the regression equation, regression linearity test, regression significance test, correlation coefficient and determining the coefficient of determination. With the help of software SPSS 17.0, the regression equation \( \hat{Y} = 2.098 + 0.536X_1 \)

The equation regression means that if \( X_1 = 0 \) is students do not have generational abilities, but still obtained global meta-level abilities of 2,098. This shows that the global meta-level ability of students is not only influenced by the generational abilities of students, but there are other factors that influence. The regression model obtained also shows that the global meta-level ability of students increases by 0.536 for an increase in a generational ability score student's.

To find out the influence of generational students ' ability on global meta-level abilities in SPSS anova output, obtained \( \text{sig} = 0.00 < 0.05 \) and output coefficient \( \text{sig} = 0.00 < 0.05 \) so that there is an influence (there is a linear relationship) of generational students' ability on global meta-level ability.

From the SPSS output, the correlation coefficient value \( (r) = 0.536 \) means that increasing the generational ability of students increases the global meta-level ability of students. From the calculation results also obtained \( r^2 = 0.314 \). This value shows that the value of the global meta-level ability of students is influenced by the generational ability of students by 31.4% through regression \( \hat{Y} = 28.915 + 0.476X_1 \). The remaining 68.6% determined by other factors.

3.2. Both the results of
Data used in this test is the test result data algebraic thinking, transformational ability of students represented by \( X_2 \) and the global meta-level ability of students represented by \( Y \). By using SPSS 17.0 software, the regression equation obtained \( \hat{Y} = 2.545 + 0.582X_2 \). The regression model obtained also shows that the global meta-level ability of students increases by 0.582 for an increase in one score of transformational abilities students'.

To find out the influence of transformational abilities students ' on the ability of global meta-level levels in the SPSS ANOVA output, \( \text{sig} = 0.00 < 0.05 \) and output coefficient \( \text{sig} = 0.00 < 0.05 \) so that there is an influence (there is a linear relationship) of transformational abilities students' on global meta-level capabilities.

Based on the results of the SPS out of the correlation coefficient, \( (r) = 0.670 \), which means that there is a strong enough positive relationship that also increases the transformational abilities students', and also increases the global meta-level abilities of students. From the calculation results obtained the
coefficient is terminated $r^2 = 0.449$. This value shows that the value of global meta-level abilities of students is influenced by transformational abilities students by 44.9% through regression $\hat{Y} = 2.545 + 0.582X_2$ remaining 55.1% determined by other factors.

3.3. Third Results

The data used in this test are thought algebra test data, generational capabilities of students represented by $X_1$, transformational ability of students represented by $X_2$ and the ability of students' global meta-globally expressed by Y. By using software SPSS 17.0, the regression equation $\hat{Y} = 1.827 + 0.20X_1 + 0.461X_2$. To test linearity of regression, obtained sig $= 0.000 < 0.05$ with a regression coefficient test obtained for the coefficient $X_1$ obtained sig $= 0.020 <0.05$ and for the coefficient of $X_2$ obtained sig $= 0.000 < 0.005$ so that there is an effect of $X_1$ and $X_2$ on Y and the regression equation obtained means (there is a linear relation $X_1$ and $X_2$ with Y). Correlation coefficient value ($r$) $= 0.689$ which means there is a strong enough relationship between generational abilities and transformational abilities of students with students' global meta-level abilities, with the magnitude of the contribution of generational abilities and transformational abilities of students with global meta-level abilities of students of $r^2 = 0.474$. Or it can be said that the ability of students global meta-level is influenced by the ability of generational and transformational students by 47.4% through regression $\hat{Y} = 1.827 + 0.20X_1 + 0.461X_2$, the remaining 52.6% determined by other factors.

Generational ability consists of (1) the ability to make equations that contain unknown elements that represent problem situations, (2) the ability to create general expressions arising from geometric patterns or numerical sequences, and (3) the ability to create expressions of rules governing numerical relationships [7]. The curriculum of the junior high school in Indonesia puts these 3 abilities on different material. The ability to make equations that contain unknown elements that represent problem situations is given to students as material that leads from thinking arithmetic to algebraic thinking. This research takes algebraic material in junior high school so that the generational ability in the research in question is the ability to make equations that contain unknown elements that represent problem situations. The structure of algebraic material in Indonesia makes students must first understand generational abilities before understanding transformational.

The results of this study are the generational ability to influence the global meta-level ability of students, while the second result in this study is transformational ability influences the global meta-level ability of students. From these two results it can be stated that the two capabilities each affect global meta-level abilities. This is in accordance with the statement that in the global meta-level capabilities contain generational and transformational capabilities that support problem solving, modeling, general pattern determination, estimation, justification and verification [16]. The results of this study are also supported by descriptive analysis according to the grouping of generational abilities.

The generational ability of students in the lower group has an average of 39.6, with an average of 43.3 students' transformational abilities, average global meta-level abilities. 33.3 students, which are presented in graph 1 below

![Figure 1. Generational abilities of lower group students](image-url)

From this descriptive analysis students with low generational abilities also have low transformational and global meta-level abilities. This is consistent with the results of the regression and correlation
obtained. This needs to get the attention of teachers to strengthen the basic basis of generational algebraical thinking because it affects the ability of other algebraical thinking.

The generational ability of students in the medium group has an average of 60.31, with an average of 66.2 students' transformational abilities, the average global meta-level ability of 50.92 students presented is shown in graph 2.

![AVERAGE OF MIDDLE GROUP](image)

**Figure 2.** Generational ability of middle group students

From this descriptive analysis students who have middle generational abilities also have middle transformational abilities but have low global meta-level abilities. This indicates that global meta-level abilities are abilities that are relatively difficult for students to master compared to generational and transformational abilities. This needs to get the attention of teachers to pay more attention to learning in the global meta-level, because with medium and transformational abilities, it is evident that its global meta-level ability is still low.

The generational abilities in the high group have an average of 87.4, with an average student transformational ability of 74.8, the average global meta-level ability of students is 57.55. Which is presented in graph 3.

![AVERAGE OF HIGH GROUP](image)

**Figure 3.** Generational ability of high group students

From this descriptive analysis students with high generational abilities have high transformational abilities and low global meta-level abilities but the global meta-level abilities in this high group have the highest scores compared to the medium and low groups. This indicates that the higher the generation capability and transformational capability, the higher the global meta-level capability. This is also consistent with multiple regression analysis that influences generational ability and transformational ability to global meta-level capabilities. With these results it is necessary for the teacher's attention to strengthen the basic basis of generational and transformational algebraical thinking in algebra learning to support and improve the global meta-level abilities of students.

4. Conclusions
Based on the results of the research and discussion, conclusions can be drawn as follows: (1) students' generational abilities have a positive effect on the global meta-level abilities of students; (2) students' transformational abilities have a positive effect on students' global meta-level abilities, (3) generational and transformational abilities together have a positive effect on students' global meta-level abilities.

References
[1] Ulusoy F 2013 *J Educ Instr Stud world* 3 1 139
[2] Agoestanto A, Isnarto I, Sukestiyarno YL, Rochmad R, and Lestari MD 2018 *Int J Instr* **12** 1 1431
[3] Magiera MT, den Kieboom LA, and Moyer JC 2013 *Educ Stud Math* **84** 1 93
[4] Radford L 2014 *Math Educ Res J* **26** 2 257
[5] Lehtinen E, Brezovszky B, Pongsakdi N, Rodríguez-Aflecht G, Veermans K, and McMullen J 2017 *Learn Instr* **49** 178
[6] Policy E 2011 TIMSS 2011 Encyclopedia 1
[7] Kieran C 2004 *Math Educ* **8** 1 139
[8] Hayati L 2013 *Proceding Seminar Nasional Matematika dan Pendidik Matematika* (Yogyakarta: FMIPA UNY) pp 978
[9] Panasuk RM 2010 *Education* **131** 2 235
[10] Blanton ML, and Kaput JJ 2011 *ZDM* **37** 1 34
[11] Lozano M-D 2015 *ZDM* **47** 2 223
[12] Ayalon M, and Even R 2015 *Int J Sci Math Educ* **13** 2 285
[13] Pedersen IF 2015 *Int J Sci Math Educ* **13** 1 71
[14] Girit D and Akyüz D 2016 Necatibey Eğitim Fak.Elektron Fen ve Mat Eğitimi Derg. **10** 2 243
[15] Godino JD, Neto T, Wilhelmi M, and Ake L *Proc Ninth Congr Eur Soc Res Math Educ* **2015** 426
[16] Palatnik A, and Koichu B 2017 *Educ Stud Math* **95** 3 245