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Students' thinking preferences in solving mathematics problems based on learning styles: a comparison of paper-pencil and geogebra

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Abstract. The purpose of this study was to analyze students' thinking preferences in solving mathematics problems using paper pencil comparing to geogebra based on their learning styles. This research employed a qualitative descriptive study. The subjects of this research was six of eighth grade students of Madrasah Tsanawiyah Negeri 2 Trenggalek, East Java Indonesia academic year 2015-2016 with their difference learning styles; two visual students, two auditory students, and two kinesthetic students.. During the interview, the students presented the Paper and Pencil-based Task (PBTs) and the Geogebra-based Task (GBTs). By investigating students' solution methods and the representation in solving the problems, the researcher compared their visual and non-visual thinking preferences in solving mathematics problems while they were using Geogebra and without Geogebra. Based on the result of research analysis, it was shown that the comparison between students' PBTs and GBTs solution either visual, auditory, or kinesthetic represented how Geogebra can influence their solution method. By using Geogebra, they prefer using visual method while presenting GBTs to using non-visual method.

1. Introduction

Research studies showed that the students use visual (such as graphic) and non-visual (such as Algebraic, verbal, and numeric) methods while solving the mathematics problems [1, 2]. Visual methods involve visual imagery and non-visual methods do not involve visual imagery [3]. The recent technology devices support the assessable and affordable visualization from the idea of mathematics to the visual imagery. It also supports the non-visual method by organizing the data and computing it effectively and accurately [4]. By investigating the student's solution methods in solving mathematics problems, researchers contend that the students have a cognitive preference for visual or non-visual solution methods [5]. This cognitive preferences determine the methodological type to which students belong.

By using an innovative technology, visualization has become an important part of mathematics education. Curriculum reformation efforts in the mathematics education proved the importance of the process of visual and the use of visual representations [4]. Besides, the connecting of the visual and non-visual representations, it is expected to be able to produce a better understanding about mathematics [6, 7, and 8]. It is proved that technology build the relationship with the difference computer program and offer a wide range of students' perspective with the visual support [9].

The importance of visualization in the problem solving is also stated by Rif'at. He argued that to solve the mathematics problems, there is a need a visual presentations beside analytical presentations.

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Despite the presentation has been exploited in the instruction, it is taken as a device to assist the instruction, so the problem solving analytically done. Whereas, the visual presentations is not only exploited as a tool to assist but also exploited as a strategy as well as a thinker in solving a problem specifically a visual-characterized and visualized problem [10]

Technology devices are not only support visual representation but also show the relationship among different representations. NCTM proved the importance of students' ability in choosing, implementing, and interpreting mathematics representation [4]. The students had got a deep understanding about the concept after they investigate and synthesize the relationship between graphic and analytic representation [11]. The effective mathematics product might be exist through the coordination for both graphic and numeric representation as well as algebra [9].

Technology assists coordinating the difference representation. It consists of a set of computer which specifically designed to serve this coordination like Geogebra [12]. Geogebra software supports several representations by offering several devices to make a graph function, show the expression of algebra, and performing numeric counting. It also support the data from numeric into visual representation. Some researchers state that the ability to employ every representative and interpret among representations will reveal a deep understanding about mathematics [13].

The effect of thinking preferences in the students' learning and working during the use of technology has been the most important subject in the late decade. The study of the topic shows the different result. Study the effect of instruction of dynamic geometry environment of students' work toward the geometry task such as determining the width of triangle and parallelograms [14]. They also investigate whether or not using a dynamic geometry can reduce students' cognitive burden by accommodating their different thinking preferences. The research result shows that there is no relationship between thinking preference and the students' work toward the geometry tasks. In his research, verbalizer utilizes visual instruction more than a dynamic geometry software. However, the result come into a contrary with the previous research result in the mathematics education [15]. It states that optimal learning is happened since the students are thought with the appropriate way of their thinking preference. Riding and Douglas also found out that verbalizer can accomplish the assignment better than those visualizer (analytical thinking) in the text-based environment while visualizer can do better than those verbalizers in every visual and graphic presentation [16].

Krutetskii's research concluded that there is a correlation between the ability of visualizing abstract relationship and the ability of geometry concept of space. Nevertheless, both of them are not the important component of the mathematics ability. Furthermore, he found out that the strength or weaknesses of visual or analytical thinking does not determine how far the students' mathematics ability is but determines the kind of it. It means that someone who have a different correlation mathematics ability between two components mentioned in the previous sessions (visual-pictorial, verbal-logical). This correlation determine thinking domain (analytic, geometric, and harmonic) where the people comes from [2].

Yerushalmy's research report states that the students experience the positive effect from the use of technology in the Algebra instruction, specifically in the field of symbol, equality, and the problematic context [17]. In addition, Yerushalmy, Shternberg and Gilead conducted a research focused on the software that support visualization [18]. Sirin Coskun conducted a multi-cased research about the effect of technology of the students' visual and non-visual thinking preference by comparing the strategy to solve the Algebra paper-based test (PBTs) of Senior High School students in Florida, USA. In his research, Coskun found out the comparison between their PBTs and GBTs shows is this dynamic software can influence their solution method [2].

2. Method

This current research has employed a qualitative descriptive method. The subject of this research was eight graders of the second semester academic year 2015-2016. This current research was conducted in MTsN 2 Trenggalek, East Java Indonesia which consisted of six students who had different learning

style: two visual students, two auditory students, and two kinesthetic students. Students who were selected as participants in this study were those who have a good communication, good in operating Geogebra program, and have one of dominant learning styles among others which was shown by a higher score obtained from learning styles test for all learning styles consisting of auditory, kinesthetic, and visual learning style.

Table 1. Research Subject Based on Their Learning Style

No	Code	Visual Score	Auditory Score	Kinesthetic Score	Learning Style
1	LN	36	27	24	Visual
2	ESP	37	32	29	Visual
3	ATR	36	38	34	Auditory
4	NDP	33	36	24	Auditory
5	FAM	30	32	36	Kinesthetic
6	YE	28	31	36	Kinesthetic

The data collection was obtained from questionnaires, test, observation, and interview. Questionnaires of learning style were used to get the data about the students' learning style. Meanwhile, a test in this study was in the form of paper and pencil-based test (PBTs) and Geogebra-based test (GBTs) which were used to get the data about the students' visual and non-visual thinking preferences in solving mathematics problems. The questionnaires used in this study had been employed by Sagitasari which consisted of 30 items [19], while PBTs and GBTs tests were adopted from Sirin Coskun that consisted of 10 mathematic problem [2] which many adaptation compatible with the students of MTs or secondary level as a subject of this study, they were number 6, 7, and 8 .

The data analysis used in this study was obtained from two sources; first, students' learning style analysis by adding all scores obtained by the students based on their learning style, they were visual, auditory, and kinesthetic learning style. Those data were then compared by those three sources obtained by the students. The highest score obtained by the students indicates their learning style; second, the students' visual and non-visual thinking preferences in solving mathematics problems employed a model of Miles & Huberman. The activity of data analysis were reduction, data display, and drawing conclusion or verification [20]. Choi-Koh [28] studied Effect of a graphing calculator on a 10th-grade student's study of trigonometry and also Huntly et al [29] studied Effects of Standards-based mathematics education: A study of the Core-Plus Mathematics Project algebra and functions strand.

3. Research Result

The result of the research showed that all of the students who have either visual learning style, auditory learning style, or kinesthetic learning style used non-visual method to solve PBTs which consists of 10 items except number 1 and 2. Both of them were solved by kinesthetic students using visual method. The students who have visual learning style used a procedural way, while the students who have auditory learning style prefer using verbal logic. This was shown from the result of the students' presentation in solving PBTs as shown in this following question:

PBTs 1	*Altogether there are 8 tables in a house. Some of them have four legs, and the others have three legs. Altogether they have 27 legs. How many tables are there with four legs?*

The students with visual learning style solved PBTs 1 by using non-visual solution method, that was separated the table with four legs as x and a table with three legs as y, they used elimination mixed method and substitution. Subject LN eliminate x earlier so that she found the value of y, then, she

found the value of *x* by substituting it. Meanwhile, subject ESP eliminated *y* earlier so that she found the value of *x*, then, she found out the value of *y* by substituting it. However, both of them found out the same result.

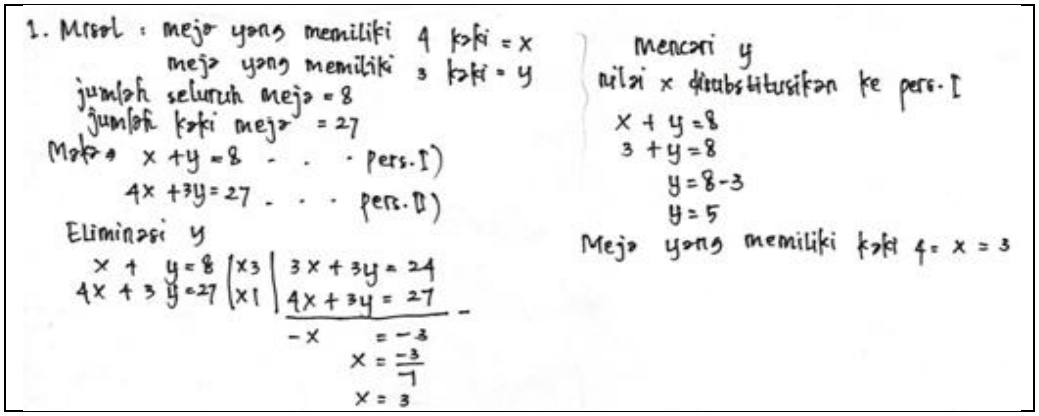

Figure 1. ESP's Solution in Solving PBTs 1

All of the students who have an auditory learning style solved PBTs 1 using non-visual solution method by guessing the number. ATR guessed the number if there were three tables that consisted of four legs so $4 \times 3 = 12$, legs left = 15, then, it was divided by 3, it became 5. She found out that there were three tables that has four legs. Meanwhile, NDP guessed that there were five tables that has three legs so it became 27 if they add them. Even though they used different way to count but they have the same way of thinking, they prefer using their logical way of thinking.

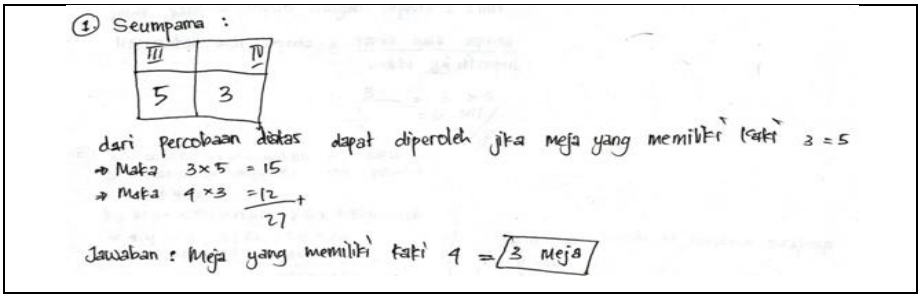

Figure 2. NDP's Solution in Solving PBTs 1

The students who have kinesthetic learning style, they tend to solve PBTs 1 using visual solution method. Subject FAM solved this problem by drawing a table. Firstly, she pulled the tables as if they have only three legs, then she added the legs to the table and it reaches 27. On the other hands, subject YE drew a table that has four legs and three legs so she found out the numbers of legs are 27. Secondly, subject FAM and YE found out the same final result they were the tables that has four legs and three legs.

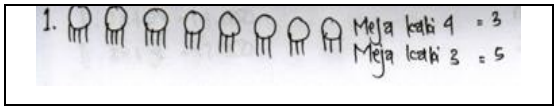

Figure 3. FAM's Solution in Solving PBTs 1

PBTs 3, PBTs 5, PBTs 6, and PBTs 7 were solved by all students who have visual, auditory, and kinesthetic learning style using elimination and substitution mix method. Meanwhile, PBTs 4, PBTs 8, PBTs 9, and PBTs 10 were solved using verbal logic and logical way of thinking. The following figure is the result of students' presentation towards PBTs 4 and PBTs 9.

PBTs 4	*Budi rode his bike to his friend Eko's house, which was 18 miles away. After he had been riding for half an hour, he got a flat tire. He walked his bike the rest of the way. The total trip took him 3 hours. If his walking rate was one-fourth as fast as his riding rate, how fast did he ride?*

All of the research subjects either visual, auditory, or kinesthetic learning style used the same way in solving PBTs 4 by using the speed formula and reducing into the formula of $distance\ (s) = speed\ (v) \times time\ (t)$. After they find $v_2 = 4$, then they findv_1 by multiply v_2 with 4, therefore they found v_1 equal to 16. So, they found that the speed is 16 mil/hour.

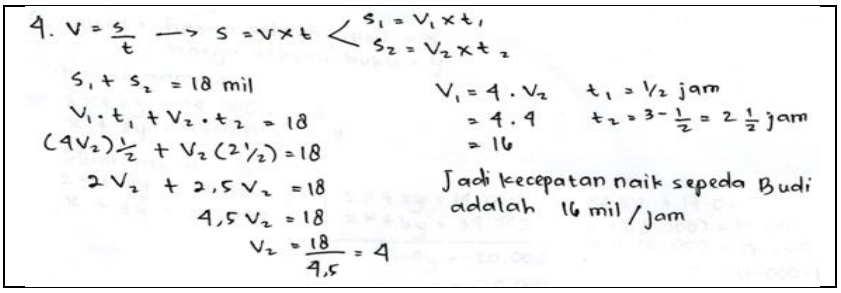

Figure 4. LN and ESP's Solution in Solving PBTs 4

PBTs 9	*There are 9 boys to every 10 girls in a particular high school. There are 2622 students at the school. How many girls are there?*

All the subjects of the research solved PBTs 9 by using non-visual method, it is a guessing numbers. If the number of the girls were 10, it would be 9 for boys, but their numbers reach = 19 (wrong), then they guessed other numbers. If the number of the girls were 100, it would be 90 for the boys, but their numbers reach = 190 (wrong). Finally, they found the number of the girls were 1380 girls and 1242 boys. Therefore, the number of them were 2622 (correct).

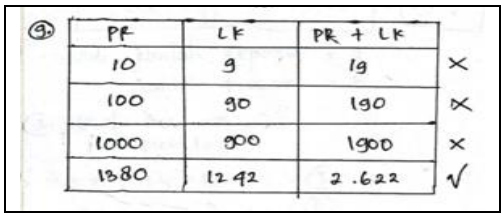

Figure 5. NDP's Solution in Solving PBTs 9

After accomplishing all Paper-based Tasks, they turned to the following steps, it was delivering Geogebra-based Tasks (GBTs) that consisted of 10 items followed by conducting an interview. While the students work and solve the problem using GBTs, it had been provided by an installed dynamic software called Geogebra where the students can select to use visual solution method in the form of graph as well as non-visual solution method in the form of numeric by opening the window *spreadsheets* as well as Algebra by opening the window *Computer Algebra System* (CAS).

The result of the research shows that all the students who have visual, auditory, and kinesthetic learning style employed visual solution method to solve all the Geogebra-based Tasks, except GBTs 4 and GBTs 9. They would solve the problem by numeric or algebra representation. The comparisons which were could not made by them are the comparisons which were could not found by them as they learn in the class. The comparison which is not in the form of $ax + by = c$ as stated in the example of GBTs 9.The following is the solution method used by the students in solving GBTs 1, GBTs 4, and GBTs 9.

GBTs 1	*Bill had Rp 10.500 coin money, in one thousand coins and five hundred coins. If he had 17 coins, how many coins he had?*

All the subjects used the same solution method to solve GBTs 1, it is a graphic representation assisted by the window of Algebra. They told that *x* as a coin of five hundreds while *y* as a coin of one thousand. They made equations $x + y = 17$ and $1000x + 500y = 10500$, then they drew a graph of both equations, then they found out intersection point of graphs. They interpreted the intersection point and stated that there had to be 4 coins of one thousand and 13 coins of five hundreds.

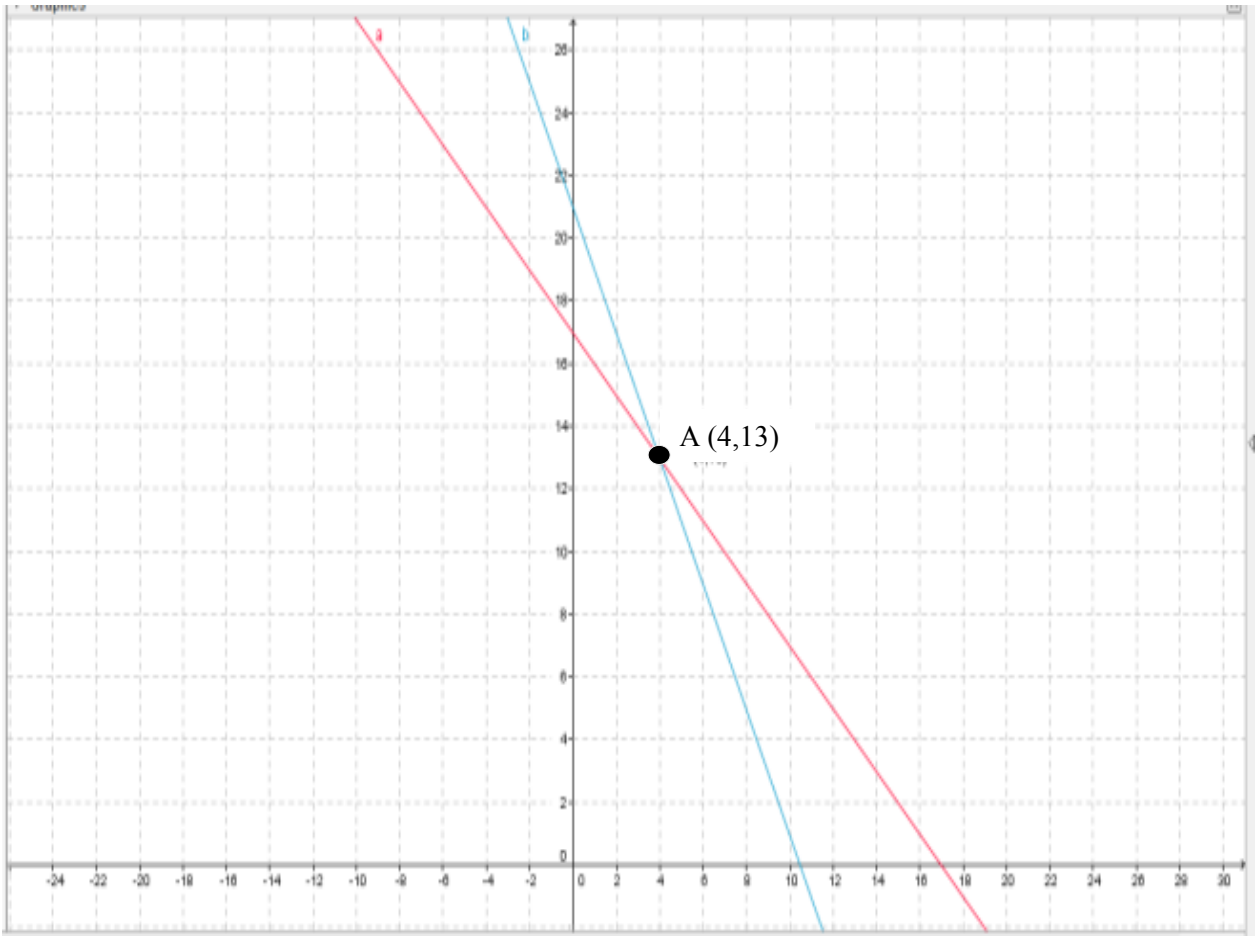

Figure 6. All subject's solution in Solving GBTs 1

GBTs 4	*An airplane trip for five hours is 640 mil. It is flight by different speed. After flying for two hours, the pilot flies the airplane twice faster that the first flight. How fast the speed for the first and second flight in that trip?*

Subject LN, ATR, and FAM used solution method which were different from the subject ESP, NDP, and YE which are still categorized as non-visual. Subject LN, ATR, and FAM use numeric method assisted by spreadsheet display till they found the same value in cell C4 and D4, it was 2560.

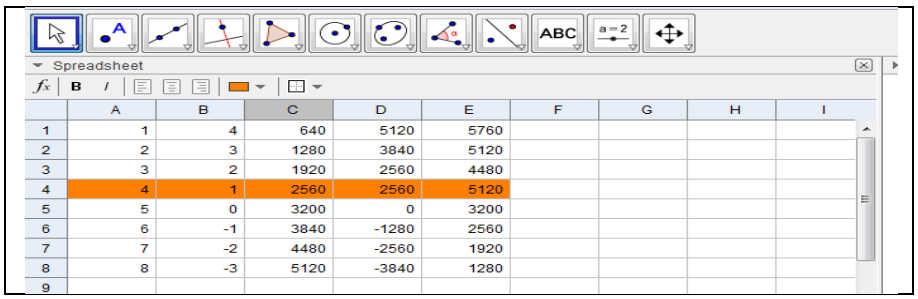

Figure 7. LN, ATR, and FAM's Solution in Solving GBTs 4

Meanwhile, ESP, NDP, and YE used Algebra representation by opening the window CAS, they assumed the first speed = x and the second flight speed = y until they found the value of $x = 80$ and $y = 160$. They interpreted the first flight speed was 80 mil/hour and the second flight speed was 160 mil/hour.

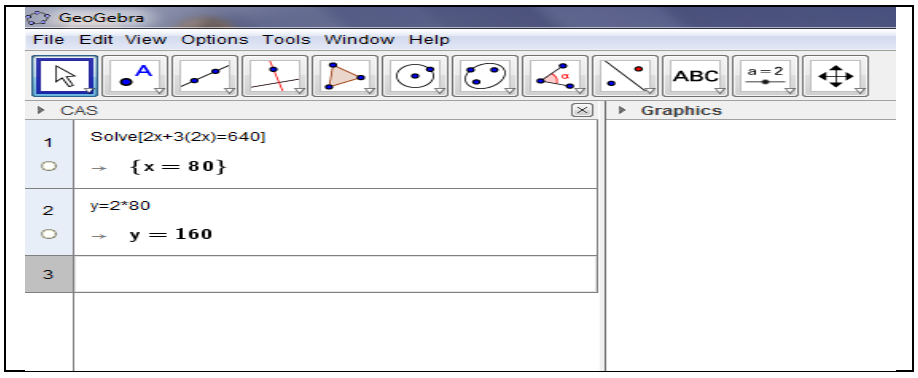

Figure 8. ESP, NDP, and YE's Solution in Solving GBTs 4

GBT 9	*There are 2 students wearing glasses to every 7 students not wearing glasses in a particular classroom. There are 63 students in that classroom. How many students are wearing glasses?*

All subjects of visual, auditory, and kinesthetic learning style solved GBTs 9 using numeric method. They inserted 2 into cell B1 and 7 in cell C1 to represent the number of students who wear glasses and those who don't wear glasses. In the second row, they inserted 4 to cell B2 and 14 in cell C2. They selected cells to create the remnant from the pattern. They drag the pattern till the fifteenth row. After they investigated the seventh row number till it was found 63 in cell D7, they stated that there were 14 persons who wore glasses

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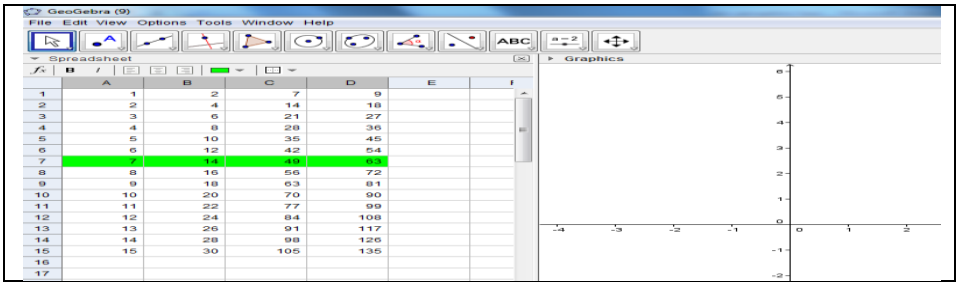

Figure 9. Solution of All Subject in Solving GBTs 9

At the first step, they would like to use graph representation but they couldn't solve the problem using a graph because they couldn't make equations.

4. Discussion

Technology devices give an opportunity to the students to use some representations. However, all the students who have either visual, auditory, or kinesthetic learning style state that they prefer solving GBTs problem using graphic representation because it is accessible easily. The Geogebra program has provided the Algebra window to draw a graph even the smallest scale of that graph.

This result supported the finding of Harskamp et. al. He reported that the function of automatic graphic picture of Geogebra and the availability of coordinate system are the important factor that caused this result. Whereas, the Geogebra did not support the visualizers. The automatic creation from the toolbar in *spreadsheet* page supported the non-visualizer. However, the students tend to use visual solution more often in solving GBTs than those in PBTs [21]. Slavit's research result shows that the students who use a graph is only when they found a problem that should be solved with a graph. This research finding was not support Slavit's finding because the students often use a graph in this study in solving mathematics problem although they did not found problems must be solved using a graph [22].

These overall research findings shows that there were different solution methods used by the students as they accomplish the paper and pencil-based task and Geogebra-based task. All the subjects of this research either students of auditory, kinesthetic, or visual have a powerful preference to think verbal logic as they solve paper and pencil-based task. The most selected main method is a numeric and an algebra, so it can be stated that most of them have non-visual preference thinking as they solve mathematics problem without any Geogebra assistant. Nevertheless, while they are provided by Geogebra, their thinking preference turn to change into a powerful preference to think visually. As they solve Geogebra-based task using a main method, they prefer to use a graph. This evidence proved that Geogebra influences students' visual and non-visual thinking preferences in solving mathematics problems. This research support the previous finding performed by Coskun who found an effect of Geogebra on students' non-visual and visual thinking preferences.

This current study also support the finding of Ruthven [23], Harskamp et al. [21], and Yerushalmy [1]. They reported that the students use different solutions as they solve the problem using technology. Harskamp et al. stated that the group of experiment use a strategy of graph more than a controlled group. However, there is no significance differences between the use of Heuristic (Guess and Check) and Algorithmic strategy [21].

Due to the use of Geogebra affects students preference to use visual representation compared with the paper pencil-based solution, the second usage of this technology might support the second usage of visual and non-visual representation which involve their visual and non-visual thinking. As has been stated in the previous session, researchers argue that the ability to use visual and non-visual representation as well as interpret both of them will affect a deep understanding about mathematics [13, 2].

The National Research Council identifies the significant indicator of conceptual understanding as the ability to use a different representation in the mathematic situation as well as to know how the form of different representation could be beneficial for different purposes [24]. For this reason, there is a close relationship between the representation fluency and conceptual understanding as well as improve the result of representation fluency in developing a conceptual understanding [2].

Some representation theories argue that the most important factor to understand the idea of mathematics is the ability to interrelate the representation to obtain the representational fluency and interpret the ideas of mathematics in different representation [25]. The result of this research shows that the use of a dynamic software facilitate the process of students interpretation to support previous findings performed by Choi-Koh [26] and Huntley et al. [27]. Therefore, the use of a dynamic software might contribute the students' conceptual understanding by supporting their representation fluency.

5. Conclusion and Suggestion

Based on the result of questionnaires, tests, observation, and interview to the students, the researcher found out that Geogebra has influenced students' visual and non-visual thinking preferences in solving mathematics problem for the students who have visual, auditory, and kinesthetic learning style. The students' responses toward PBTs and GBTs reveal the important information about their thinking. They use various type of representations as they solve the mathematics problems. Auditory and kinesthetics' students whose basically prefer non-visual but when they used geogebra, they changed their preference into visual. All the subjects have a difference solution in solving PBTs and GBTs, this difference indicate the changing of their preference to think visually or non-visually as they solve the problem within two different instructional media.

Realizing that this research limits the scope only on mathematics problems that can be solved by the linier equality and two dimension graph, further research can be broaden by changing the students accomplishment in the form of interview, for example; mathematics involvement task that can be solved by using polynomial and three dimension graph. Subjects of the research also can be changed into the higher level; senior high school and university level.

Aknowledgements

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