Students’ mathematical thinking and their learning style

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Abstract. The purpose of this study is to describe the students’ mathematical thinking based on their own learning style. The second objective of this research is to find out which one of the learning styles which has the highest mean score of the students’ mathematical thinking. In addition, this study also aims to find out whether there is a relationship between the students’ mathematical thinking with the learning style they have. Based on the result of research, the students’ mathematical thinking mostly in the medium and high category. Meanwhile, the dimension of learning style possessed by the majority of students is an assimilating learning style. Students with moderate and high students’ mathematical thinking categories, have an assimilating learning style. The mean score of the highest students’ mathematical thinking test is obtained by group of students with converging learning style. Although there is a difference in the statistical description, but the relationship between students’ mathematical thinking with their own learning styles is not significant. Nevertheless, the knowledge of the description of these two variables can serve as a good enough reference for determining the students’ self-development direction in the future.

1. Introduction
Mathematical learning can be viewed as an active and constructive process, in which students try to participate effectively to solve problems that arise in the practice of mathematics in the classroom. In order for mathematics learning to be an active and constructive process, a mathematics teacher should teach mathematics as a process that provides a challenge, so as to stimulate students’ curiosity through the given problem, and assist them in completing by stimulating. In the process of giving this stimulus, each student must have a difference in understanding and processing the information provided to him. This difference is called the learning style.

A teacher should consider the characteristics of each student in learning, in order to determine a proper method to obtain optimal learning. This is because, if a person is forced to learn something by methods that are not his learning style, the person may feel depressed and frustrated [1]. When students understand their own learning style, it will be easier for them to learn something. Similarly, from the teacher side, teachers who understand the learning styles of their students will more likely present a teaching style that suits the needs of students. Learning styles studied in this research is the style of learning carried by David A. Kolb called Kolb’s learning style. [2] classify the learning style into four styles, that are diverging style, individuals with this style like to see phenomena based on multiple perspectives; assimilating style, individuals with this style usually understand broadly to deduce;
converging style, individuals with this style like searching for practical sides from particular theories and ideas; and accommodating style, individuals with this style prioritize their efforts in exploring challenging experiences.

The objectives of mathematics education in school include the formal and material objectives. The formal objective emphasizes in managing the logics and forming the students’ personalities. Meanwhile the material objective emphasizes the problem-solving and mathematics implementation [3]. In realizing those material objectives, a number of researchers agree that the mathematics teaching in classroom should imitate the work of a mathematician [4]. When a mathematicians pose and tackle on a mathematical problems, they processes and actions some list as follows exemplifying, specialising, completing, deleting, correcting, comparing, sorting, organizing, changing, varying, reversing, altering, generalising, conjecturing, explaining, justifying, verifying, convincing, refuting. Its activities, according to [5] is an activity that will establish a students’ mathematical thinking. Meanwhile,[6] propound that there are four fundamental processes that can form mathematical thinking, i.e.: specialising that is trying special cases and looking at examples, generalising that is looking for patterns and relationships, conjecturing that is predicting relationships and results, convincing that is finding and communicating reasons why something is true.

Mathematical thinking is closely related to the mathematical literacy. [7] examine that some frameworks provided to illuminate mathematical thinking, going beyond the ideas of mathematical literacy. Mathematical literacy is a term popularised especially by the OECD’s PISA program of international assessments of fifteen-year-old students. Mathematical literacy is the ability to use mathematics for everyday living, and for work, and for further study, and so the PISA assessments present students with problems set in realistic contexts. The framework used by PISA shows that mathematical literacy involves many components of mathematical thinking, including reasoning, modelling and making connections between ideas. [7] declares that people will need to use their mathematical thinking skill when trying to solve particular problems using mathematics. Consequently, it can be said that the students’ achievement in mathematics subject is also can be identified base on their mathematical thinking skill.

The success of learning process, can be seen from mathematical thinking ability that is achieved by students. Meanwhile, the success of teaching and learning process can’t be separated from the students’ learning style. Therefore, the authors presume that there is a relationship between the students’ mathematical thinking and their learning style. Both variables will be examined in a study entitled Analysis of Students’ Mathematical Thinking Based on Their Learning Style. The purpose of this study is to describe the students’ mathematical thinking based on their own learning style. The second objective of this research is to find out which one of the learning styles which has the highest mean score of the students’ mathematical thinking. In addition, this study also aims to find out whether there is a relationship between the students’ mathematical thinking with their learning style.

2. Methods
This research is a descriptive research conducted in SMA N 3 Subang, Indonesia. The population in this study is all students of class XII. Meanwhile, the samples taken are class XII IPA 2. Sample taken by purposive sampling, considering that the students of class XII IPA 2 are students who have heterogeneous learning styles, so the writer can analyse the students' mathematical thinking in each type of learning style.

Instrument in this research is test of mathematical thinking, learning style inventory (LSI) adopted from Kolb and McCarthy [8] and observation sheets. The instrument to measure the mathematical thinking, is a mathematics problem that consisting of seven items that contain an indicator of mathematical thinking proposed by [6], as follows, specialising that is trying special cases and looking at examples, generalising that is looking for patterns and relationships, conjecturing that is predicting relationships and results, convincing that is finding and communicating reasons why something is true.

Learning style inventory (LSI) consists of 36 items of statements with four alternative answers. The four kinds of alternative answers are scores that must be chosen by the students describing the proximity.
of each statement with their own personal condition, as follows, number 4 illustrates that the statement is very appropriate with the condition of students, number 3 illustrates that the statement appropriate with the conditions of students, number 2 illustrates that the statement somewhat appropriate with the conditions of students while the number 1 illustrates that the statement is less appropriate with the conditions of students. Each score is summed by the group of statements specified by LSI. This group of statements is accumulated in scores that reflect a person's preference when acquiring a new knowledge. [1] explains that some people perceive new information through concrete things, relying on their own senses (concrete experience). Some others tend to make symbolic or abstract representations, perform analysis and make systematic planning (abstract conceptualization). Meanwhile, there are people who process their experiences by observing others involved in the experience, then reflecting on what happens (reflective observation). Others prefer to engage directly and take action (active experimentation). This combination of individual preferences creates a learning style dimension [9]. The illustration of the combination of these two preferences can be seen in Figure 1. The LSI scores obtained by each student will map out what preferences they have and belong to what learning style dimension.

![Figure 1. Kolb’s Learning Style.](image)

3. Result and Discussion
The data of this study consist of the scores of students’ mathematical thinking, LSI scores and observation results. The score of students’ mathematical thinking test are grouped into three categories, namely low, medium and high. This grouping is done by forming frequency distribution tables with the number of classes is three and the class lengths is nine. The following is the frequency distribution table of the scores of students' mathematical thinking test for each group.

**Table 1. The Frequency Distribution Table of Students' Mathematical Thinking Test Scores**

| No | Groups | Interval scores | Frequency | % |
|----|--------|-----------------|-----------|---|
| 1  | Low    | 2-10            | 9         | 24 |
| 2  | Medium | 11-19           | 16        | 42 |
| 3  | High   | 20-28           | 13        | 34 |

If referring to table, most of students have mathematical thinking skill at medium level. According to the data of the research results, the mean score of the students' mathematical thinking test as a whole is 14.97 with the standard deviation of 7.10. Meanwhile, the proportion of students who scored higher than mean score on mathematical thinking was 63.2%. It also shows that more than half of the students have above average mathematical thinking.
In this study, students’ learning styles are grouped based on the analysis results from LSI that has been filled by each student following the steps of determining learning dimensions put forward by Kolb and McCarthy [8]. The following is a breakdown of the mean value and standard deviation of the students’ mathematical thinking test based on their learning style.

| No | Groups       | Frequency | Mean  | Standard deviation |
|----|--------------|-----------|-------|--------------------|
| 1  | Diverging    | 5         | 15.20 | 7.73               |
| 2  | Assimilating | 17        | 16.06 | 7.43               |
| 3  | Accommodating| 11        | 12.45 | 7.30               |
| 4  | Converging   | 5         | 16.60 | 5.13               |

Table 2. The Descriptive Statistics for each Groups of Learning Style

In Table 2, it is found that the highest mean value of students’ mathematical thinking is in the group of students with converging style. [2] argue that students with this style prefer to find the practical side of the theory or idea. They will feel satisfied when they can make the right decisions and solve the problem thoroughly so that they are more interested in technical tasks than talking about theoretical issues. Because of this students’ mathematical thinking is measured by looking at their way of solving mathematical problems, it is clear that this group of students with this style will be superior in their mathematical thinking compared to other groups of students.

Table 2 also suggests that the lowest mean value of the students’ mathematical thinking test scores occurred in the accommodating group of students. Based on the theory put forward by [2], students with this style, prioritize the exploration of challenging experiences, they like to accomplish tasks with others both in planning goals, completing field assignments and experimenting with ways which is unique and creative in completing the task, consequently, when they are given the mathematical thinking test and solve it independently, they find it difficult.

Based on the results of the observation, it was found that students with converging styles in their daily lives had a quiet character, they had good academic abilities, however, they did not have a good side of confidence. Meanwhile, the characteristics of students with accommodating styles, they are more confident in expressing ideas, except that their academic abilities are still within the average limit. The learning style is influenced by the nature and the environment. Thus, there is a tendency for each student’s learning style to change according to the educational environment. Based on Table 2, students with converging styles have better mathematical thinking than accommodating, but that does not mean that students with accommodating styles cannot be better, this can be a teacher’s capital, to create a learning environment that can optimize potential these two student characters.

The learning style that dominates the students is the assimilating style. Students with this style, usually like a theory that can be rationalized or logical rather than practical values. In activity, they like activities such as reading, exploring analytical models, and spending much time thinking deeply [2].

Based on the psychology, the grade XII high school students begin to have a learning independence that is developing [10]. [11] suggests that the grade XII high school students are generally in the final teen phase, wherein this phase they are in the realistic stage. It is in line with the theory put forward by [2] which mentions that in students with assimilating learning styles, they have a rational and logical nature. Both leads them to think things deeper. This nature will undoubtedly emerge if they already have good learning independence. Therefore, it is reasonable that at this age, the majority of students have an assimilating style. Table 2 also shows that students with an assimilating style also have an average mathematical thinking ability that is above the overall average.

In this study, every aspect of mathematical thinking is measured by several types of questions. For example, to measure generalizing aspects, students are given two different types of questions as follows.
Table 3. The Types of Questions for Generalizing Aspects

| Type I                                      | Type II                                                                 |
|---------------------------------------------|-------------------------------------------------------------------------|
| Consider the following sequence of numbers. | Someone invested 10 million rupiah in a bank with                        |
| \[ 2, 1, 8, 32, \ldots \]                  | 12\% annual compound interest. If \( U_3 \) state the                   |
| a) Specify the next three numbers of the    | amount of investment after the end of the 3rd year.                    |
| sequence.                                  | a) Determine the amount of \( U_3 \).                                   |
| b) Determine the 10\(^{th}\) term of the    | b) Determine the amount of investment after the end of the 4\(^{th}\)   |
| sequence.                                  | and 5\(^{th}\) year.                                                   |
| c) Determine the \( n \)^{th} term of the   | c) Find the relationship between the amount of investment after the     |
| sequence.                                  | end of the 4\(^{th}\) and 5\(^{th}\) year.                            |
| d) Can you determine the \( n \)^{th} term  | d) Determine the relationship between \( U_{n-1} \) and \( U_n \).       |
| formula of the sequence?                   |                                                                        |

The results showed that each student with each type of learning style was able to solve type I questions. However, only students with assimilating styles were able to solve type II questions. Type II problem is a contextual problem, which requires a deeper level of thinking compared to type I questions. Students with assimilating styles have a very rational and logical nature to abstract contextual questions into mathematical theory. Some of the students with this learning style are even able to finish perfectly the matter of type II.

Diverging is a style of exploration, students with this style like to see phenomena based on multiple perspectives. Usually they love working in groups, more open to ideas and appreciate feedback even if personal. The number of students with this style is the same as the number of students with the converging style. The mean value of students’ mathematical thinking test in this group is quite good, it’s still above the average overall student. The majority of students in this style worked on ability test questions smoothly, especially questions related to the aspects of specializing. This is of course because students with this style are able to see concrete situations in a variety of perspectives, so the process of trying questions by paying attention to simple cases is something that can be considered easy. Here is one of the questions about the aspects of specializing that are given to students.

Table 4. The Types of Questions for Generalizing Aspects

Determine the difference between the 25\(^{th}\) term and the 23\(^{rd}\) term from \( u_n = \left( \frac{-n}{n+1} \right), n \in \mathbb{N} \).

The thinking stage of students is diverged between concrete experience and reflective observation. The problem in the table above is a type of problem that is simple and often done by students, so students have concrete experience with the problem. Observation of students with diverging styles on this problem, will bring their thoughts directly to the experience they have experienced. Thus, they have no difficulty at all when faced with this type of problem. 80\% student with diverging styles done this problem perfectly.

Furthermore, this study also aims to determine whether there is a significant relationship between the students' mathematical thinking with their own learning style. To achieve the objectives of the study, then made a grouping score of the students’ mathematical thinking test and learning styles in table of tabulation data. This table is depicted on the number of students in each group combination of students' mathematical thinking and learning style. This table also will be used to test the independency between the variables of students’ mathematical thinking with learning styles. Here is a tabulation data between the variables of students’ mathematical thinking with learning styles.
Table 5. The variables of students’ mathematical thinking with learning styles

| Groups  | Diverging | Assimilating | Accommodating | Converging | Sum |
|---------|-----------|--------------|---------------|------------|-----|
| Low     | 1         | 4            | 4             | 0          | 9   |
| Medium  | 2         | 6            | 6             | 2          | 16  |
| High    | 2         | 7            | 1             | 3          | 13  |
| Sum     | 5         | 17           | 11            | 5          | 38  |

In Table 5, the highest value is in the groups of students who have top mathematical thinking skills with assimilating styles, and the observed frequencies are above the expected one. In line with the previous discussion, groups of students with assimilating styles are dominating high school students of class XII, and the average group of students is above the average of all students, so it is not surprising if this group has the most significant number of students. Table 5 also illustrates that there is no single student in the group with a converging learning style that has low mathematical thinking skills. It was also in line with the previous discussion which suggests that the group of students with a converging style is the group of students who are the most superior ability of the mathematical thinking. Based on Table 5, there are zero observation frequencies, then the freedom test using the Fisher Exact Test. The analysis of freedom is to see whether the variables of mathematical thinking ability with learning styles are independent or not. Here are the test results.

Table 6. The Result of Independency Test

|                      | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) |
|----------------------|-------|----|----------------------|---------------------|
| Pearson Chi-Square   | 5.853 | 6  | 0.440                | 0.479               |
| Fisher's Exact Test  | 6.024 |     | 0.440                |                     |
| N of Valid Cases     | 38    |    |                      |                     |

Table 6 shows the significance value of Fisher's Exact Test is 0.440. It is higher than alpha 0.05. Thus, the two variables are independent. In other words, there is no significant relationship between students' mathematical thinking ability and learning style. This freedom test is a basis for determining the statistical analysis for testing the differences in mathematical thinking ability in each learning style of the students. Also, the determination of statistical tests is also related to the normality of the data. Therefore, before testing the differences in mathematical thinking skills in each learning style of students, then first test the normality of data scores test ability mathematical thinking that grouped by their learning style. The following is the result of the normality test.

Table 7. Normality Test of Mathematical Thinking Capability Test Score Based on Student Learning Styles

| Learning style of mathematical thinking scores | Kolmogorov-Smirnov Statistic | Kolmogorov-Smirnov df | Kolmogorov-Smirnov Sig. |
|-----------------------------------------------|------------------------------|-----------------------|-------------------------|
| Test of mathematical thinking scores          | Diverging                    | 0.290                 | 5                       | 0.198                   |
|                                              | Assimilating                 | 0.191                 | 17                      | 0.099                   |
|                                              | Accommodating                | 0.231                 | 11                      | 0.105                   |
|                                              | Converging                   | 0.346                 | 5                       | 0.050                   |

Based on Table 7, it appears that all data groups do not have a standard normal distribution. Therefore, to examine differences in mathematical thinking ability of students based on learning style used statistical test Kruskall-Walis. Here is the result.
Table 8. Difference Test of Students’ Mathematical Thinking Based on Their Learning Styles

| Test score mathematical thinking | Chi-Square | Df | Asymp. Sig. |
|---------------------------------|------------|----|-------------|
|                                 | 2.694      | 3  | 0.441       |

Based on Table 8, the significance value of the Kruskall-Walis test is 0.441. This value is higher than the alpha 0.05. Therefore, there is no statistically significant difference test score of mathematical thinking ability in each learning style of students. In other words, although descriptively there is a difference between students' mathematical thinking skills based on their learning styles, but it’s not significant. The difference that occurs in the data is characteristic of the class sample only. This distinction cannot be further generalised to all members of the population. However, the results of this study can be beneficial for teachers and students of class XII IPA 2 SMA N 3 Subang. This study provides an overview of the learning styles of each student in the class, so that in the future, teachers can direct them in learning according to their learning style. As stated by [1], the more a teacher understands the learning style of her students, the more likely it is to present the teaching style that suits the needs of the students and can also help if the students have learning difficulties. [12] has conducted research related to several learning methods suitable for use in each learning style of his students. Groups of students with diverging learning styles are more appropriate if they learn by using lecture methods, question and answer methods, and task methods; students with accommodating learning styles would be better if their learning method uses real-world problems. Meanwhile, students with converging learning styles are more suitable to use procedural and discussion techniques. It is, of course, can be a reference for teachers in learning in the classroom.

Likewise, with the students, if they understand his learning style, it will be easier for him to learn something and increase his motivation to show his best ability. According to [9], for the last three decades, researchers have found consistency between learning styles and other variables, such as personality types, educational specialities, professional careers, job roles, and adjustment competencies. High school students’ XII grade are final year students at high school education, after which, they must make choices in developing themselves in the future. According to [9], students who have converging styles will be more interested in natural science and engineering. Meanwhile, students with diverging styles, they prefer to explore language, literature, history and other social sciences. The groups of students with assimilating styles have an interest in the field of science and mathematics. Whereas, students with accommodating styles, they tend to show interest in the field of business field studies and techniques, an appropriate career for students with this style includes sales and marketing.

Knowledge of students’ mathematical thinking and learning styles can be a reference in determining their career choices forward. Mathematical thinking ability is a skill that can give an idea about the economic development of a country [7]. Thus, this ability is relatively essential for every student than others. Most students have mathematical thinking skills at a medium level and they have an assimilating style. It is in line with the opinion of [9] where students with this learning style tend to have a connection in the field of mathematics and science. Although there is no significant difference between students' mathematical thinking skills based on their learning styles, knowledge of these two variables can be a good reference to determine the students' self-development in the future.

4. Conclusion

Based on the finding of research, the majority of students’ mathematical thinking are in the medium and high category. Meanwhile, the majority of students have an assimilating style dimension. Students with medium and top mathematical thinking skills have an assimilating style dimension. The highest average score of students’ mathematical thinking test is in the student group with the converging style. Although
there is a difference in the statistics description, the relationship between students’ mathematical thinking with learning styles is not significant. Nevertheless, the knowledge of these two variables can be a good enough reference to determine students' future development. Recommendations for further research is whether the students’ mathematical thinking can influence students in choosing their career path in the future.

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Acknowledgments
I would like to express my gratitude to Kemenristekdikti (Ministry of research, technology, and higher education) of Indonesia for providing research grant for this project.