**The use of mind mapping to improve connection ability of mathematics**

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**ABSTRAK**

**Kata Kunci:**.

**ABSTRACT**

*Students still experience difficulties in finding the connection between a math topic, both with other math topics and with other disciplines and with everyday life in the process of learning mathematics in the classroom. This is because the element of connection in learning rarely appears. Accordance with this, it is necessary to use the right strategy to improve students' connection skills, one of which is the use of mind mapping. This type of research is a quantitative descriptive with a pretest-posttest design. The research population was one of the public high schools in the city of Padang with a sample of one class in class XI IPA. The data in this study were collected through pre-tests (limit function), question sheets containing mind maps, and final tests (derivatives). The collected data were analyzed descriptively and using inferential statistics in the form of a t-test. The results showed that the students' mathematical connection skills in class XI IPA were better than before. In addition, students' ability to make connections between math topics (K1), with other disciplines (K2) and with the real world/daily life of students (K3) has increased compared to before. Based on these results it was concluded that students' mathematical connection abilities increased after learning using mind mapping.*

**Keywords:** *mind mapping strategy, mathematical connection ability, limits and derivatives.*

## Introduction

Teachers, students, curriculum, facilities and infrastructure have a close relationship with the learning process in the classroom. The teacher has the task of choosing the right learning model and media in accordance with the material presented in order to achieve educational goals. Until now, students have found many difficulties in learning mathematics because they are dominated by abstract concepts (Firmanti & Yuberta, 2021). As a result, students find it difficult to understand the next concept because the prerequisite concepts have not been understood. These condition show that what is the goal of learning mathematics not to be achieved optimally. Permendiknas No. 22 concerning Mathematics Subject Content Standards (Depdiknas, 2006) states that one of the objectives of learning mathematics for SMA is to understand mathematical concepts, explain the interrelationships between concepts and apply concepts or algorithms, in a flexible, accurate, efficient, and precise manner, in problem solving.

Connection has two different views, namely standards relating to the relationship between mathematical ideas and the relationship to the real world and other subjects. Students should be able to see that an idea in mathematics builds on another idea. Students are also led to see that mathematics plays an important role in the arts, sciences, and social sciences. Through learning that emphasizes the ability to connect ideas in mathematics, students not only learn mathematics, they also learn about its uses in mathematics. Therefore, connection ability is an important part of mathematics (Siagian, 2016)..

Students' views of mathematics will be broader through mathematical connections because they are not only focused on certain content and give rise to positive traits towards mathematics itself. (Isnaeni et al., 2018). In this mathematical connection ability students are expected to: be able to recognize and utilize the relationship between mathematical ideas, understand how mathematical ideas are interconnected and underlie one another to produce a unified whole, and recognize and apply mathematics inside and outside mathematics (National Council of Teachers of Mathematics, 2000). In other words, the ability of mathematical connections is divided into three aspects of connection groups (Anita, 2014), namely: Aspects of connections between mathematical topics (K1), Aspects of connections with other disciplines (K2), and Aspects of connections with the real world of students/connections with everyday life (K3).

Based on existing data, the ability of mathematical connections in Indonesia is not maximized (Puspitasari et al., 2019). High school students tend to be in the medium category. In this category, students are able to understand mathematical concepts but still tend to be less precise (Dwiwandira & Tsurayya, 2021). In addition, students are not given the opportunity to seek and find their own knowledge and relate it to real life situations, so that students' mathematical connection abilities are not maximally facilitated (Abidin, 2020).

The problem of educational development, especially in improving students' connection abilities in existing mathematics learning, must be resolved by teachers and related parties in an effort to improve students' abilities, including mathematical connection abilities (Gordah, 2012). One of the causes of students' low mathematical connection abilities includes the application of inappropriate learning models (Nugraha & Basuki, 2021). Therefore, efforts that can be made by educators are to innovate in learning. Seeing these conditions, an approach or learning model is needed that is able to develop students' mathematical connection abilities, so that the goals of learning mathematics are achieved to the fullest (Septian & Komala, 2019). For this reason, the authors try to apply mind mapping strategies in learning mathematics.

Mind mapping is a learning strategy that develops the abilities of the left brain and right brain by describing things that are general and then moving on to things that are specific in a map. Mind mapping gives freedom to each student to construct students' own ideas or concepts so that they are easy to understand (Indriani, 2010: 4).. The mind map is an incredible storage, data retrieval, and access system for a gigantic library, which actually resides in our amazing brains. With a mind map, every new piece of information that we enter into our library is automatically "linked" to all the information that is already there. The more memory links attached to each piece of information in our heads, the easier it will be for us to "hook out" whatever information we need. With a mind map, the more we know and learn, the easier it will be to learn and know more (Buzan, 2009).

In addition, according to Tony Buzan (in Husni: 2018), Mind Map is a note-taking technique that can map creative and effective thoughts and integrate and develop the working potential of the brain, both the right and left hemispheres of the brain contained in a person. (Husni & Zainuddin, 2018). The form of the diagram is like a tree diagram and its branches make it easy to refer one piece of information to another. In addition, the use of worksheet-based mind mapping can also improve student learning outcomes [(Listari, 2020)(Srimuliati et al., 2022)] and have a positive influence on learning [(Bagaskara et al., 2020)(Krisdiyanti et al., 2019)(Bagaskara et al., 2020)].

Learning mathematics through mind mapping can foster students' mathematical connection and problem solving abilities, because this approach does not require students to memorize facts, but encourages students to construct knowledge in their own minds using mind maps. In addition, students are able to make connections with mathematics (intertopics), other lessons or problems related to real life. Based on this, researchers are interested in seeing how the development of students' mathematical connection abilities by using mind mapping

**Methods**

This type of research is a combination of quantitative research and descriptive research. Quantitative research was used to investigate whether or not there was an increase in students' connection abilities with mind mapping strategies. Descriptive research find to document, describe, and analyze the conditions under which infants and children live and learn (Kosie & Lew-Williams, 2022). For this case, descriptive research is used to find out how students' connection abilities develop. The quantitative research design used in this study was the pretest-posttest design. The population in this study were students of class XI IPA SMAN 10 Padang. Sampling was carried out by means of purposive sampling, namely the technique of determining the sample with certain criteria and considerations. The class that meets the considerations is class XI IPA-4 because it is a class that has a high percentage of completeness but still lacks mathematical connection abilities. The research instrument was a math ability test consisting of 9 questions which included questions K1, K2 and K3. Another instrument used is a problem sheet in the form of mind mapping.

**Results**

**Mathematical connection ability**

Pretests and posttests were given to research subjects and data were obtained according to Table 1 below:

Table 1. Pretest and Posttest Results of Students' Mathematical Connection Ability

|  |  |  |
| --- | --- | --- |
| Data | Pretest | Posttest |
|  | 45.25 | 76.06 |
|  | 105.04 | 52.65 |
|  | 10.25 | 7.26 |
| N | 33 | 33 |
| Max Value | 63.64 | 87.33 |
| Min Value | 28.41 | 58.00 |

Based on the table above, it can be seen that the average score of students' mathematical connection skills increased by 30.81 points, from 45.25 to 76.06. Statistically, the calculation is done by t-test. From the results of calculations with the t-test obtained = 16,13 and = 1,70. Because , then H0 is rejected or H1 is accepted. It can be concluded that students' mathematical connection abilities are better after applying learning with mind mapping.

Furthermore, the scores of pretest and posttest are then grouped based on the connection aspect. From these scores, the average and standard deviation calculations were carried out which can be seen in Table 2 below:

Table 2. Scores of Each Aspect of Students' Mathematical Connection Ability

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Connection Aspect |  | | S | |
| Pretest | Posttest | Pretest | Posttest |
| 1. K1 | 57,68 | 76.79 | 13,16 | 12,60 |
| 1. K2 | 34,49 | 78.41 | 8,53 | 16,23 |
| 1. K3 | 45,92 | 72.01 | 8,81 | 14,83 |

Information:

K1 : Interrelationships between topics in mathematics

K2 : The relationship between mathematics and other disciplines

K3 : The relationship between mathematics in everyday life

The data in the table above shows an increase in students' mathematical connection skills in every aspect of the connection observed. The average score for the highest aspect of students' mathematical connection ability is in the aspect of connection between mathematical topics (K1). The standard deviation for K1 data after using mind mapping is smaller. Means, the ability to connect between mathematical topics in solving problems after using mind mapping is almost the same. In addition, the highest score increase is in the K2 aspect. This shows that at first students were not used to connecting mathematics with other disciplines, but mind mapping has helped overcome this.

**The development of mathematical connection skills using mind mapping**

1. **Aspect of K1**

Pretest problem concerning the ability to connect to mathematics are about limits. The K1 aspect can be seen from the relationship between limits and algebra, limits with derivatives and limits with trigonometry. This can be seen in question number 1 pretest with details on the percentage of students who answered 10 students (30.30%) answered correctly and 23 students (69.69%) answered incorrectly. Most of the mistakes made by students in working on problem number 1 lie in associating algebraic topics. They have difficulty in factoring, algebraic operations and unsystematic work procedures. Students are not able to factor f(x+p)-f(x) in the right way. The student's error lies in deciphering the shape , it should be:

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Then in the division = ,, students immediately cross out the p value, the form should be factored in the form , even though the result obtained is 2x. Unlike the answer models above, there are also other answer models in question no 2 pretest. Students have started to think by giving examples in the form of variables and numbers in mathematics, but have not been able to interpret them. As the example given: students write the form for the limit relationship with the derivative of the function. This shows that mathematics is still characterized by a collection of numbers or formulas.

After the pretest, the learning process is carried out using mind mapping. Furthermore, the mind maps that have been made by students are observed to see various aspects of mathematical connection abilities including aspects of K1. The image below shows the student's first work by filling in the blank boxes provided.



Figure 1. Mind Map Calculating Derivatives of Simple Functions

The K1 aspect is shown by the student's activity in finding the definition of derivative. In calculating the derivative of a simple function there are three branches and students must complete the steps on these branches sequentially. The other form of mind mapping on the K1 aspect is in the form of conclusions obtained by students, made in the form of a mind map as shown in Figure 2 below:



Figure 2. Mind Map Made by Students at Meeting IV

The K1 aspect of the posttest questions can be seen from the link between derivatives and other topics in mathematics such as: limits, algebra, compositional functions, trigonometry and binomial theorem. This can be seen in question number 1 regarding the relationship between the derivative and the limit. If each item is traced, the score for each item can be described as follows: for question number 1, 20 students (60.60%) answered correctly and 13 students (39.39%) answered incorrectly. Other data showing aspects of K1 in the final test can be seen in solving problem number 2, namely when looking for the first derivative of Students can use the derivative formula or use the distributive property by multiplying in first and then deriving. This shows the relationship between derivatives and algebra. The results of the percentage of students who were able to answer were as follows: 6 students (12.12%) were able to answer and interpret their answers correctly. Nineteen students (57.57%) were able to answer but were unable to interpret their answers correctly and 8 students (24.24%) were able to answer correctly but were unable to interpret them. Students can conclude well the relationship between derivatives with limits and derivatives with trigonometry. Derivatives can be used to calculate the value of a function limit by finding the derivative of the limit to produce an indeterminate form. This shows the use of mind mapping to improve students' mathematical connection abilities.

Based on the description and analysis of the data above, it can be concluded that there has been an increase in connection ability, especially for aspects of connection between mathematical topics (K1). Students' difficulties in associating limits with other topics in mathematics can be overcome by mind mapping. This is proven in the final test, students are able to associate derivatives with other topics in mathematics.

1. **Aspect of K2**

In pretest, 31 students made mistakes in working on question number 3, most of them did not understand the meaning of the question asking about instantaneous speed. Students tend to say that in finding speed is distance divided by time, according to their initial knowledge. Other data showing aspects of K2 can be seen in question number 4 which tests students' ability to make direct connections between derivatives and other disciplines such as physics and economics. The percentage of students answered with the following details: 7 students (21.21%) blanked their answer sheets, 17 students (51.51%) were able to make a small part of the K2 aspect connection and 9 students (27.27%) could only make half aspect of K2. From the data above it can be seen that the initial connection ability of students for the K2 aspect is still low. After learning to use mind mapping, students begin to be able to design their own mind maps as shown in Figure 7 below



Gambar 7. *Mind Map* Koneksi dengan Disiplin Ilmu Lain

In posttest, the K2 aspect can be seen from the relationship between derivatives and other disciplines, namely speed and instantaneous acceleration in physics and the rate of change of price to quantity in economics. Problem number 4a asks that the instantaneous velocity is obtained from the first derivative of distance. This resulted in data: 14 students (42.42%) were able to answer correctly and 19 students (57.57%) answered incorrectly. Problem number 4b asks that the instantaneous acceleration is obtained from the first derivative of velocity. For question number 4b, 14 students (42.42%) were able to answer correctly, 19 students (57.57%) answered incorrectly. In this case students work on problems in various ways. There are those who use formulas and without using derivative formulas for division. Thus the answer is obtained in a simpler way using the chain rule.

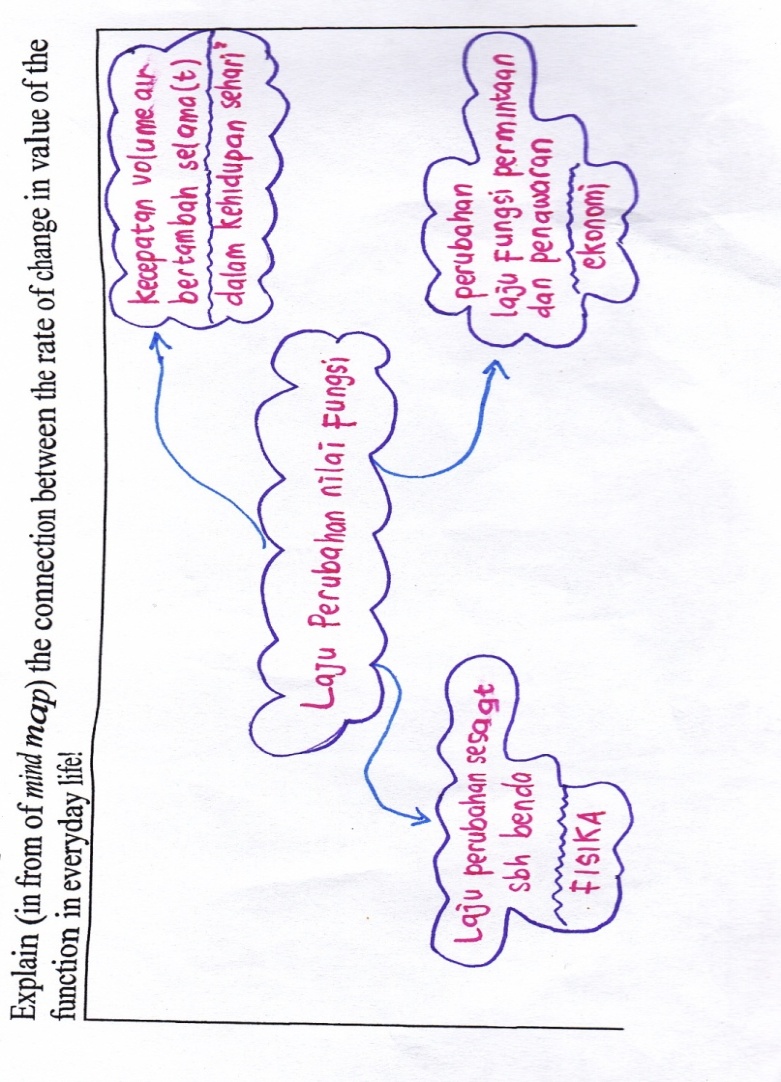
In posttest, the final test given also tested students' ability to express K2 aspects directly, as seen in question number 6. If in the initial test 7 students (21.21%) blanked their answer sheets, in the final test there were no students that blanks the answer sheet. Five students (15.15%) were able to make some connections, 21 students (63.63%) were able to make half connections, 7 students (21.21%) were able to make most connections and 1 student (3, 03%) were able to make the connection correctly.

The mind map made by students as shown in Figure 14 has an influence on answering questions on the final test. This shows the use of mind mapping to improve students' mathematical connection skills, especially aspects of K2. Based on the description and analysis of the data above, it can be concluded that there has been an increase in connection capabilities, especially for the K2 aspect. Students' difficulties in associating limits with other disciplines can be overcome by mind mapping. This is proven in the final test, students are able to associate derivatives with other disciplines.

1. **Aspect of K3**

In pretest problem, most of the students' mistakes in working on K3 aspect questions lay in understanding the questions. Students calculate the amount of profit simply by multiplying it by the number according to the year requested. Even though what is requested is the instantaneous profit rate when t = 2. Other data showing students' ability to associate limits with the real world of students (business) can be seen in question number 6. The percentage of students who answered with the following details: 9 students (27.27 %) blanked the answer sheet, 19 students (51.51%) were able to make a few connections, five students (15.15%) were able to make half the connections.

In improving the K3 aspect, during the research, students were also directed to make mind maps which were assisted with problem sheets. The form of a mind map for K3 aspects can be seen in the image below:



Gambar 14. *Mind map* yang Dibuat Siswa pada Pertemuan VI

Based on the figure above it can be concluded that it is known that students have been able to formulate the use of derivatives. The three branches represent the application of derivatives to various areas of everyday life, such as: determining the instantaneous rate of change of water volume and instantaneous velocity using derivatives in physics, and the rate of change of price to quantity in economics.

The K3 aspect in posttest can be seen from the relationship between derivatives and business, derivatives with the rate of change of the volume of water in the tank and in other daily life. This can be seen in question number 7. In general, students have been able to answer well. This can be seen from 25 students (75.75%) able to answer correctly and 8 students (24.24%) answered incorrectly. Another data showing K3 aspects can be seen from question number 8 asking about the use of derivatives in calculating the rate of change of volume of water in the tank. The description of the data obtained showed that none of the students interpreted the answers even though 18 students (54.54%) answered correctly. Fifteen students (45.45%) answered incorrectly. Students are able to use derivatives to determine the rate of change of volume of water in a tank using the chain rule. The form is changed to . Then derived using the chain rule to obtain . This is not the only solution answer.

Students infer the uses of derivatives in everyday life, such as calculating the profit rate of a business and determining the rate of change of volume of water in a tank. The mind map made as shown in Figure 20 has an influence on making the above conclusions. This shows the use of mind mapping to improve students' mathematical connection abilities. Based on this, it can be concluded that there has been an increase in connection capabilities, especially for the K3 aspect. Students' difficulties in associating limits with everyday life can be overcome by mind mapping. This can be proven in the final test, students are able to associate derivatives with applications in everyday life

In addition, students make mind maps at the end of learning. Of the five exercises given, each student has a variety of solutions and forms of thought. There are those who finish with short stages, there are also quite long stages. Mind map value data for each meeting can be seen in Table 6 below:

Tabel 6. Nilai *Mind Map* Siswa

|  |  |  |  |
| --- | --- | --- | --- |
| Pertemuan  Ke | Jumlah  Siswa |  |  |
| 2 | 33 | 37,88 | 18,00 |
| 3 | 33 | 78,79 | 18,51 |
| 4 | 33 | 75,00 | 15,03 |
| 5 | 33 | 84,85 | 12,18 |
| 6 | 33 | 71,59 | 13,83 |

Based on Table 6, the average value of the students' mind maps at the second meeting was still low, namely 37.88 and began to increase for the third and fifth meetings. This is because students have started to understand how to make a mind map. However, at the fourth and sixth meetings the value of the students' mind maps decreased from the previous meeting, because at these meetings students made their own mind maps without direction from the teacher.

**Discussion**

Based on the description of the data above, it is known that the ability of students' mathematical connections after implementing learning using mind mapping is better than before implementing learning with mind mapping. This is because, previously students still had difficulty understanding and applying mathematical concepts in working on practice questions. Students prefer to copy friends' work or wait for the discussion given by the teacher. Students are less willing to try to find their own answers to the questions given. This is in line with Listari's research which states that mind mapping is appropriate for use in the learning process (Listari, 2020).

However, the teacher provides opportunities for students to see mathematics as a whole when learning with mind mapping. This causes students to be interested in thinking about the relationships that exist between topics in mathematics and outside mathematics. In accordance with Buzan's opinion, the mind map is an extraordinary storage, data retrieval and access system for a giant library, which actually exists in our amazing brains. With a mind map, every new piece of information that we enter into our library is automatically "linked" to all the information that is already there (Buzan, 2009). The more memory links attached to each piece of information in our heads, the easier it will be for us to "hook out" whatever information we need. With a mind map, the more we know and learn, the easier it will be to learn and know more.

Every mind map branch provides an opportunity for students to relate topics in mathematics, such as the topic of derivatives and limits. This is included in one of the aspects related to the ability of mathematical connections. In accordance with Coxford's opinion (in Siagian) which states that students must be given the opportunity to be able to see the relationship of conceptual and procedural knowledge including propositions and propositions, between theory and theory, between topics and topics, or between branches of mathematics and other branches of mathematics (Siagian, 2016).

Every student has a way of solving and various forms of mind maps. At the third meeting students are free to fill in the mind map that has been provided. There are students who fill in their answers neatly in the boxes provided and find their way on other paper. But there were also students who filled in their answers by looking for answers directly in the blanks provided. This is so as not to hinder student creativity, regardless of the right or wrong answers that have been made.

Mind mapping strategies can create a synergy of thoughts and growth from both sides of the brain. Buzan (2006: 40) states that "mind maps allow us to see the overall picture at any time, and allow us to see the relationships or links that exist". So that students' memory of lesson concepts, especially mathematics, becomes strong and students can understand the interrelationships between aspects of mathematics topics or aspects of mathematics with other disciplines and the real world of students. So that students are able to express all the connections that exist in their minds. This includes a love of mathematics. This shows that students' interest in mathematics is increasing. For more details, it can be seen in Figure 19 which is below.



Gambar 19. *Mind map* Aturan Rantai

The aspects seen in the mind map above are aspects of K(1). The teacher guides students how to answer the problem to find the derivative of the compositional function which is finally found together using the chain rule. This activity involves a connection process between the composition function and the chain rule. Based on this, it can be concluded that there was an increase in students' mathematical connection abilities, especially for aspects of K1. This is due to the use of mind mapping in the learning process. In addition, other effects of this strategy were also found. Based on Figure 28 it is known that mind mapping can change the character of students to prefer mathematics.

K2 aspects related to other disciplines can be seen at the fourth meeting. At this meeting, the teacher and students discussed the relationship between the derivative and the instantaneous speed. Instantaneous velocity is the first derivative of distance ( whereas instantaneous acceleration is the first derivative of velocity (. This can be seen in Figure 20 below



Gambar 20. *Mind map* yang Dibuat Siswa pada Pertemuan IV

In the mind map above, you can clearly notices the connection between the image and the branch. Like the speedometer picture made by students as a symbol of speed. This explains the link between mathematics and physics, where speed is the first derivative of distance. While the image of a right-angled triangle represents trigonometry. These pictures help students remember longer. This is in accordance with the opinion of Buzan (2009: 5) who says that all mind maps have something in common and have a natural structure that emanates from the center. Everything uses curved lines, symbols, words and pictures according to a set of rules that are simple, basic, natural, and according to how the brain works. With a mind map, long lists of information can become colorful, highly organized, and easy to remember diagrams.

In addition, it is difficult to distinguish between aspects K2 and K3 in the test questions. So this is a limitation in research, because it also affects the assessment for aspects of K2 and K3. One of the reasons is that aspects of K2 and K3 both belong to connections outside of mathematics which are interrelated with one another. It is hoped that in the future there will be clear specifications for these two aspects.

**Conclusions**

The mathematical connection ability of class XI IPA students after learning mathematics using mind mapping is better than before using mind mapping. The ability of students in connection aspects between math topics (K1), with other disciplines (K2) and with the real world/daily life of students (K3) during the application of learning with Mind Mapping tends to increase. In addition, learning using Mind Mapping can be used as an alternative for mathematics teachers to improve students' mathematical connection skills. To be able to improve students' mathematical connection skills even better, students should be trained regularly in working on questions of mathematical connection ability.

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