Building Learning Paths of Students’ Creative Thinking Circle Topics by Applying The Scaffolding Metacognition Approach

K M A Fauzi¹, Yasifati Hia²

¹Faculty of Mathematics and Natural Science, State University of Medan
²Faculty of Mathematics and Natural Science, State University of Medan

e-mail: aminunimed29@gmail.com

Abstract. Mathematics is knowledge which generally has prerequisite material that students must have to understand new material. This means that to understand a material in mathematics learning trajectory is needed. Prior knowledge is the most crucial thing that makes students able to connect all existing information so that they can construct new knowledge through the process of assimilation or accommodation. This study aims to: (1) build student learning trajectories in solving problems about circles, (2) find out how students' creative thinking abilities with learning paths are designed that apply the Scaffolding metacognition approach. This type of research is Design Research to improve the quality of learning. In this study the researchers gave 3 items about the ability to think creatively. Two trials were conducted, the first trial was conducted in class A and the second trial was conducted in class B. The results of the study indicate (1) There are 3 phases in the learning trajectory of students' creative thinking abilities, namely: 1. Analysing, including determining information from questions, selecting important information, and choosing the right strategy in solving it; 2. Identifying, including determining the adequacy of the elements in the problem, making mathematical models, and can describe the problem; 3. Evaluating, including finding and detecting important matters in the problem and drawing appropriate conclusions. (2) The results of students' creative thinking ability tests in trial 1 shows that students have not been able to solve problems optimally. Students' lack of understanding of the concept of a circle and determining the circumference of a circle make it difficult for students to solve problems regarding the length of the tangent circle. By developing the previous learning trajectory, in trial 2 there was an increase in students' creative thinking abilities. The design of a correct learning trajectory is also very influential in increasing the ability of students. And make the learning process fun and meaningful so that students will remember knowledge in long-term memory.

Keywords: Creative thinking ability, learning trajectory, scaffolding, metacognition approach, and circle

1. Introduction

All human activities such as communicating with something and the environment, drawing conclusions what is seen, felt, and heard, are not separate from thinking. Thinking is manipulating or managing and transforming information in memory [1]. Thinking is done to form concepts, reason and think critically, make decisions, think creatively and solve problems. Thinking is a dynamic process by taking three stages, namely: the stage of formation of understanding, the stage of opinion formation...
and decision formation [2]. Through these three steps a person does the thinking stage before finally making a decision in various ways. Creativity as one of the multiple intelligences that includes various kinds of brain functions in contracting cognitive schemes. A cognitive level of students will work widely when using creativity. The creative aspects of the brain can help explain and interpret abstract concepts, thus enabling students to achieve greater mastery, in subjects such as mathematics, especially Geometry which are often difficult to understand with regard to spatial abilities in compiling their metacognition. Metacognition is: *One’s knowledge concerning one’s own cognitive processes and products and anything related to them...*metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear*[3]. The metacognition approach refers to the metacognition questions raised namely: (1) Questions about understanding the problem; (2) connection questions; (3) strategy questions; (4) reflection questions. In this approach the role of the lecturer is also very important in controlling the cognitive processes of students [4]. The questions given are a form of scaffolding that is intended to train students to control cognitive activities. Metacognition states that metacognition includes knowledge about thought processes, self-awareness and beliefs and intuition [3]. These aspects of metacognition can help students in solving creative problems. Why is that? because in the process of solving problems students need to monitor or monitor the process of thinking as to how and why they take the completion steps, whether the settlement steps are going well or there are obstacles that are able to encourage students to think of other alternatives or try to understand the problem again. Similarly states that learning with a metacognitive skills approach is very important to develop students’ abilities in learning cognitive strategies, for example: asking themselves, expanding these applications, and gaining control of their self-awareness [5]. The initial test results given indicate that there are still students who cannot analyse the questions by writing down what is known from the problem. And most students cannot describe the problem and how to calculate the length of the bicycle chain correctly. Students only use the formula to find the contact line outside the two circles and do not understand the problem well in determining the length of the bicycle chain because the chain is wrapped around the two gear gears.

Hypothetical Learning Trajectory (HLT) is an instrument that guides the process of conducting research with research as an extension of thought experiments developed by Prudential. According states HLT is made up of three companions the hypothetical trajectory is made up of three components of the learning goal that defines the direction, the learning activities, and the hypothetical learning process a prediction of how the students thinking and understanding will evolve in the contest of the learning activities [6]. The learning trajectory is made up of three components of the learning goals, the learning activities, and hypothetical process learning process [7]. It can be concluded that hypothetical learning flow is a conjecture about a series of activities that students go through in solving a problem or understanding a concept. The flow obtained based on some of these revisions is called the learning flow (learning trajectory). The illustration of the learning trajectory according is as follows:

![Figure 1. Various Student Learning Trajectories](image)

Learning will be better and make it easier for students to understand a concept with a learning trajectory by determining learning objectives, student activities in learning, as well as students' alleged thoughts[8].
2. Research Method

2.1 Research subjects and objects
The subjects in this study were students of mathematics at Medan State University. Trial I was conducted in class A and Trial II in class B. Where as the object was the tangent circle (GSL).

2.2 Research Procedures and Design
This study uses a design research method with two trials as a way to answer the problem formulation so that the research objectives are achieved. Design research is a research method that aims to develop local instruction theory through collaboration with researchers to improve the quality of learning[9]. A series of student activities consisting of conjectures or conjectures of student strategy and thinking will be developed in this study. In this research an activity based on student experience will be designed to understand the tangents of a circle. This research consists of three stages with two trials which can be carried out repeatedly until a new theory is found which is the result of a revision of the tried learning theory. Following are the steps in research design. Learning will be better and make it easier for students to understand a concept with a learning trajectory by determining learning objectives, student activities in learning, as well as students' alleged thoughts.

2.2.1. Phase I: Preliminary Design. At this stage a literature review is carried out on the circle material and a metacognitive approach so that a mathematical creative learning conjecture and trajectory can be formed. Then proceed with a discussion between the research team class conditions, research needs, schedules and ways of conducting research with the team concerned. At this stage, learning trajectory and hypothetical learning trajectory are also designed. Then from local instructional theory is formulated which consists of learning objectives. This conjecture aims as a guide (guide) to anticipate the thoughts of students who emerge and develop in learning activities. Conjectors are dynamic and can be arranged and revised during the learning process (teaching experiment).

2.2.2. Phase II: Teaching Experiment. In this second stage is testing the teaching activities that have been designed in the first stage in the classroom. This trial aims to explore and hypothesize students' strategies and thoughts during the learning process. During the process, the conjecture can be modified as a revision of local instructional theory for the next activity. The researcher acts as the instructor and other researchers as the focus of observing every activity and important moments during the trial process. At this stage a series of learning activities are carried out then the researcher observes and analyses what happens during the learning process that takes place in class.

2.2.3. Phase III: Retrospective analysis. After the trial data are obtained from learning activities in class and then analysed and the results of this analysis are used to plan activities and to develop designs for subsequent learning activities. The purpose of retrospective analysis in general is to develop a level of local instructional theory. At this stage HLT is compared with student activities to answer the problem formulation. Cyclic Design Research as follows[10]:

![Instruction Experiment](image)

Figure 2. Cycle in Development Research
3. Results And Discussion

3.1. Result

In this research, a test of creative thinking ability was conducted, the test was carried out twice, namely in the trial I class A and trial II in class B which were parallel and equivalent. Provision of this test aims to determine the ability to think creatively obtained by students after being treated by applying learning based on the metacognition approach and learning trajectory designed in understanding tangent circle material. The following is a learning trajectory that was designed and implemented.

| Period | Topic | Sub Topic | Activities |
|--------|-------|-----------|------------|
| 1st period | Circle | Circle elements | Review the circle elements |
| 2nd period | Line that offends a circle | Paint a tangent to a circle. |
| 3rd period | Tangent length of a long circle | Determine the tangent length of the alliance in two circles. |
| 4th period | Length of the loop | Determine the length of the rope that is wrapped around several tangent circles. |

Based on Table 1 it shows the researcher wants to analyse what initial knowledge students must have in order to understand the tangent material of the circle. Initial knowledge of what is not owned by the student so that he has difficulty in understanding tangent circle material. And researchers want to know how the student's learning trajectory on tangent circles using teaching materials based on metacognition approaches. After applying the metacognition approach and hypotheses the learning trajectory was designed. Students in the first trial were given a test of creative thinking abilities. The average condition of each aspect of indicators of students' creative thinking abilities ranging from analysing, identifying, is as follows:

![Creative Thinking Ability Student](image)

**Figure 3.** Average Creative Thinking Ability of Students on each Indicator and the Difference from the Ideal Score

It appears that there is an increase in creative thinking ability from various indicators. This is caused by the learning approach used. Build a student's learning trajectory on the topic of the circle by analyzing the student's answer sheet what are the processes that students do in solving creative thinking problems in the circle. Following are the improvements experienced by students with the application of learning trails designed to be developed and learning based on the metacognition approach:
Figure 4. Increase in Students' Creative Thinking Ability in Every Indicator of Creative Thinking.

There is an increase in students' creative thinking ability in every indicator of creative thinking. This points to the impact of the metacognitive learning approach given to creative thinking ability from trial 1 to trial 2. Building student learning trajectory on the circle's tangent line, namely by analysing the results of answers to tests of creative thinking ability undertaken by students. The following questions and solutions made by students along with the results of the analysis in each trial:

**Question 1:**
Ridwan has a bicycle. The bicycle has a rear gear which is 7 cm in radius. And the front gear has a radius of 14 cm, and the distance of the two gears is 50 cm. Ridwan wants to calculate the minimum chain length he must buy to be able to use his bicycle. What is the length of the bicycle chain that Ridwan needs?

a. Analyse what information you get from the problem
b. Identify how you can solve this problem!
c. Calculate the required chain length!

Figures 5 is the student's answer to the given problem

![Trial I](image1)

![Trial II](image2)

**Figure 5.** Overview of student answers already using formulas

Analysis results:
From the student answers sheet you can know that most students are already able to write down what information is known from the problem given. Most students have been able to write the formula in use, as well as students can find out that it needs a formula around the circle \((2\pi r)\) in determining the length of the chain so that the student answers are right.

**Question 2:**
Polan works at a platform. One day the customer ordered 3 pipes of equal size with a diameter of 6 inches (1 inch = 2.54 cm). The police wanted to tie up the pipe so that it was easier for the customer to carry the pipe. What is the minimum wire length Udin needs?

a. Analyze what information you get from the problem
b. Identify how you can solve this problem!
c. Calculate the length of wire needed to tie the pipe!
Figures 6 is the student's answer to the given problem

**Trial 1**

![Image 1](image1)

**Trial 2**

![Image 2](image2)

**Figure 6.** An overview of the problems students face in solving problems

Analysis results:
From the student answer sheet, it can be seen that most students have been able to write down what information is known from the given problem. Some students also have not been able to write in full the formulas used, students are still confused about the tangent formula of the inner and outer circle circles. Students write a plan to solve the problem to determine the length of the rope on the side of the circle with $3 \times \frac{1}{2}$ around the circle = $3 \times \frac{1}{2} \pi r$ which should be $3 \pi r$. Demonstrates the initial ability of students regarding the concept of the circle is not good.

**Question 3:**
Furthermore, students are faced with the 3rd problem which aims to find out the student's analysis on the information provided, identify how the student solves the problem and calculate how long the rope is required

![Image 3](image3)

**Figure 7.** Length of a Bucket that is Wrapped Around and Connect the Two Pulleys

Each of these controls has a diameter of 21 cm and 28 cm. The closest distance between the two pulleys is 35 cm. Rina wants to calculate the length of a bucket that is wrapped around and connect the two pulleys. Help Rina calculate the length of the bucket!

a. Analyze what information you get from the problem
b. Identify how you can solve this problem!

c. Calculate the length of the rope needed!

**Trial I**

![Image 4](image4)

**Trial II**

![Image 5](image5)

**Figure 8.** Initial ability of students regarding the elements of the circle is not good.
Analysis results:
From the student answer sheet it can be seen that most students have been able to write down what information is known from the given problem. Some students also have not been able to write in full the formulas used, students are still confused about the tangent formula of inner and outer circle circles. students do not understand the concept of circle elements, students enter the same diameter value with the radius. This shows the initial ability of students regarding the elements of the circle is not good.

3.2. Discussion
In learning mathematics, it is necessary to climb the steps, if one step is lost then it is difficult for us to reach the goal, moreover, two steps are gone then we will be more difficult to go up. That is learning Thus learning mathematics one concept with another has a link, to understand the concept then we must know the concept beforehand. Therefore, the role of educators is also needed in activating student cognitive. The preparation of hypothetical learning trajectory must really be done to anticipate what mental activities must be as well as what knowledge students must have in understanding a concept in mathematics. In line with the conclusions [11] which states "From these explanations, teachers should also help ensure students have enough prior knowledge to make it easier to build new knowledge, as well as to make learning fun and meaningful so that students will remember knowledge in long-term memory. " And the research [12] "Based on these conclusions, educators should ensure that students understand the concepts of a material before continuing to the next material that requires the concept of the previous material, so that students have sufficient initial knowledge in solving the given problems ". Poor prior knowledge makes it difficult for students to connect any information, manage it, and present the questions given. Before students understand the singung circle, students are trained to paint the tangent of two circles. And initial knowledge that students must have to solve problems regarding the length of the singung circle is the elements of the circle, area and circumference of the circle, the position of the line on the circle, the length of the tangent line of the two circles and so on.

4. Conclusions
1. Tangent circle material requires prerequisite material to facilitate students in understanding the material. The most influential material to support the understanding of tangents of circles is the concept of circles ranging from elements of the circle to the area and circumference of the circle. The material is preliminary knowledge that students must have in understanding the material tangent to the circle. Therefore, it is true that the initial abilities of students are very influential in the learning process of students. The following is the preliminary design of the researcher regarding the student learning flow in achieving the goal of understanding the tangent material of the circle:
   There are 3 phases in the learning trajectory of students' creative thinking abilities, namely (1) Analyzing, including determining information from questions, choosing important information, and choosing the right strategy in solving it; (2) Identifying, including determining the adequacy of the elements in the problem, making mathematical models, and being able to describe the problem; (3) Evaluating, including finding and detecting important matters in the problem and drawing appropriate conclusions.
2. An increase in the ability to solve students' creative thinking by applying learning trajectories that are designed based on the metacognition approach. Students who are introduced to the concept of the circle circle elements know the diameter and radius, determine the circumference of the circle and the tangent concept of the circle can easily build their creative thinking and solve the problems given.

5. Recommendations
Based on the findings and conclusions on the researchers gave some suggestions are:
1. It is necessary to train students in analyzing the problems given by looking back at the problems given in terms of completeness of the problem and in writing down the description of the problem given, especially in the form of mathematical models.

2. It is necessary to redevelop the student's learning trajectory, especially in the to fik tangent line of the circle so that students can build creative thinking in solving math problems

Acknowledgements

This research is funded by the State University of Medan in accordance with the contract number: 0441/UN33/KEP/PPL/2020, dated 15 June 2020

References

[1] Santrock, John W. (2007). Psikologi Pendidikan. Jakarta :Kencana.
[2] Sagala, S. (2010). Konsep dan Makna Pembelajaran. Bandung :Alfabeta.
[3] Schoenfeld, A. H. (1992). Learning to Think Mathematically: Problem Solving, Metacognition, And Sense-Making in Mathematics. In D. Grouws (ED.).Handbook for Research on Mathematics Teaching and Learning (pp.334-370).
[4] Kramarski, B. & Mizrachi, N. (2014). Enhancing Mathematical Literacy with The Use of Metacognitive Guidance in Forum Discussion. In Proceeding of the 28th Conference of International Group for Psychology of Mathematics Education.
[5] Fauzi, A. (2015). The Enhancement of Student’s Mathematical Connection Ability and Self regulation learning with Metacognitive Learning Approach in Junior High Schoolo. Internasional Confernce On Research and Education In Mathematics (ICREM7).
[6] Bakker, A. (2003). Design Research in Statistics Education on Symbolizing and Computer Tools. Amersfoort: Wilco Press.
[7] Nurdin. (2007). Model Pembelajaran Matematika yang Menumbuhkan Kemampuan Metakognisi untuk Menguasai Bahan Ajar.UNESA. Surabaya.
[8] Soedjadi, R (2007). Masalah Kontekstual Sebagai Batu Sendi Matematika Sekolah. Pusat Sains dan Matematika Sekolah (PSMS) UNESA, Surabaya.
[9] Gravemeijer, K dan Van Eerde, D (2009). Design Research as a Means for Building a Knowledge Base for Teaching in Mathematics Education, The Elementary School Journal, 109 (5) : 510-524.
[10] Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. van den Akker, K. Gravemeijer, S. Mc Kenney& N. Nieveen (Eds.), Educational design research (pp. 17-51). London Routledge.
[11] Fauzi, A. Dirgeyase, W. I. &Priyanto, A. (2019). Building Learning Path of Mathematical Creative Thinking of Junior Students on Geometry Topics by Implementing Metacognitive Approach. International Education Studies. Vol. 12.No. 2. ISSN 1913-9020 E-ISSN 1913-9039.
[12] Mukasyaf, F. Fauzi, A. Mukhtar. (2019). Building Learning Trajectory Mathematical Problem-Solving Ability in Circle Tangent Topic by Applying Metacognition Approach. International Education Studies.Vol. 12.No. 2. ISSN 1913-9020 E-ISSN 1913-9039.