The development of mathematics teaching media based on problem based instruction to enhance grade X high school students' critical thinking

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Abstract. This research discusses the development of mathematics learning media based on problem-based instruction (PBI) to enhance students' critical thinking skill in grade X. The developed learning media are lesson plan and students' worksheets. The research was conducted until preliminary research phase including need analysis, student analysis, curriculum analysis and concept analysis by using Plomp model (Preliminary Research, Prototyping Phase, and Assessment Phase). Data collected through observation, questionnaire, and interview. The sample is Grade X students of SMAN 15 Padang. The results shown that the learning media used are not facilitating students' critical thinking skill in teaching-learning process.

1. Introduction

Critical thinking skill is one of the main competences needed to be mastered in learning mathematics. It goes with The Ministry of Education’s goal (1) the purpose of learning mathematics is to nourish students’ ability in critical thinking, logical thinking, analytical and creative thinking. Since the rapid growth of knowledge and technology and easy access to get information, critical thinking is clearly needed to prepare students well in their social life, world of work, competitive environment, and self-responsibility.

Hence, critical thinking has become one of the most important skills to face the 21st century demand. It is taught in teaching and learning process. Not only is it necessary to develop cognitive ability to store information effectively but also critical thinking is used to recognize an existing problem as well as an inquisitive attitude that seeks proof of the evidential. It involves gathering knowledge about the accuracy of this proof and the ability to make use of this knowledge and attitude [2]. Critical thinking is the disciplined mental activity of evaluating arguments or propositions and making judgments that can guide the development of beliefs and taking action [3].

According to Fisher (4) critical thinking is an active and adept skill of interpreting and evaluating in keen observation, communication, information and argumentation. In addition, Facione (5) stated that critical thinking comprises of several abilities in analyzing, drawing conclusion, interpreting, explaining, self-regulating, having inquiring and methodical mind, and problem-solving. Thus, critical thinking plays a major role in influencing students’ teaching and learning process. In short, critical thinking is a mental process which consists of problem solving, giving feedback, analyzing argument, doing observation, writing hypothesis, deduction and induction reasoning, evaluating and decision making.
The mathematics problem given to students should be designed with problem-solving assignment which needs higher order thinking skills. So, it will lead to effective learning. Students’ critical thinking skill can be observed by solving math problem correctly and following the given concept. Kwek (6) in Syurtharidho says that one of his recent findings about critical thinking emphasizes on time effectiveness in teaching learning process. Therefore, critical thinking is the main concern now.

As an educator, teacher must develop updated learning media; lesson plan and students’ worksheets. Trianto (7) states that lesson plan is teacher guidelines in conducting teaching and learning process which consist of learning activity. Moreover, the Indonesia Ministry of Education guidebook states that lesson plan consist of several learning activities for a period or more face-to-face learning. In other word, lesson plan is the main guidelines for teacher in conducting teaching and learning process. So that, they can achieve the expected learning goals and objectives effectively. The lesson plan must be arranged by their own, considering the curriculum and students’ needs, and must be carried out in the actual classroom activity as the main guidelines. Teaching and learning process will run properly if the teacher prepares a well-organized lesson plan and an interesting classroom activity in students’ worksheets.

Based on writer’s research findings of grade X students in SMA N 15 Padang, 1) Easily distracted. 2) Students’ low comprehension. 3) Unwilling to ask question. 4) Low critical thinking. 5) Incapable of solving mathematics problem. 6) Students do not pay attention. Teachers tend to use textbook and give the most common or low level assignment to the students. Consequently, students are not able to complete varied math problem which need high critical thinking in order to solve it. It leads to passive learners who just wait for teacher’s explanation. As the result, students become passive learners and are not able to explore new knowledge in solving math problem. This continuous predicament, not only make the students feel bored and unmotivated but also will create less interactive teaching and learning atmosphere.

The interview results conducted with Mathematics teachers in SMA N 15 Padang show that students cannot solve the story problem involving high critical thinking skills. They were unable to understand the topic, identify and simplify the problem. In addition, the interview results conducted on students show that they only study mathematics in school but never once at home. They tend to think that mathematics is the most difficult subject. Learning mathematics should be more focused on the progress which involve critical thinking skills such as: understanding the concept, drawing hypothesis, identifying, interpreting, solving problem, applying the concept to another problem.

The lesson plan designed by the teachers already met the national standard. Yet, the classroom activities have not supported the students to find the mathematics concept. In the lesson plan, teachers tend to explain directly to the main topic, give an example and order the students to work on their worksheets. The example is a low level problem or just a basic concept without depth explanation, meanwhile the students’ worksheets comprises various difficulty of math problem.

In the other side, students’ worksheets discussed directly to the main topic without building students’ background knowledge or involving students’ participation. The teachers fed the formula and ask them to memorize it. This is not the true intended use of worksheets. The blame should not be aimed neither at teachers nor students if everything didn’t go well as planned. To solve this predicament, teachers must be creative and innovative in choosing the appropriate learning model which suit students’ needs. As the main goal is achieving interactive learning atmosphere.

One of the most recommended learning model to achieve the goals and solve the problem mentioned above is Problem Based Instruction (PBI). PBI is a learning model based on constructivist understanding that accommodates students’ participation in authentic learning and solving problem. It prepares students to think critically and analytically, and help them to find any source to solve the math problem. Using PBI in teaching must strictly follow the proper procedure. Weist (10) Problem-oriented teaching methods support learners in finding their own solutions to substantial and relevant problems.

The math problem presented is a problem that is relevant to students’ real situation. It is aimed to motivate students, draw students’ enthusiasm and curiosity, improve students’ learning activity, and find the suitable concept. Thus, students will solve the given problem easily. Problem solving is an approach. Problem-based is a learning approach where students work on authentic problems for compiling their
own knowledge, developing inquiry and higher-order thinking skills, developing independence, and self-confidence. In brief, problem-based learning is one of the learning models that presents contextual real-world problem so the students can grasp essential knowledge and concepts from the topic discussed. In PBI, students work in small groups to solve the problem. As the teacher implementing the learning model, students may use any kind of procedure or critical thinking skills to solve the problem. The problem is based on real life situation. Students and teacher need to cooperate in using this learning model. For example, teacher explains several steps to solve the problem, teacher also provides the best strategy to complete the assignment and create flexible atmosphere where students can study at ease.

2. Method
In this research, the development model used was adapted from Plomp model. Plomp model consists of three stages: Initial investigation phase (preliminary research), development or prototyping stage, and assessment stage [11]. Preliminary analysis is conducted to obtain information about current education problem. Also through preliminary analysis, writer is able to catch a glimpse of the product being developed. In the preliminary analysis stage, these analyses were conducted: needs analysis, student analysis, curriculum analysis, and concept analysis.

Needs analysis is completed through observations and interviews. The candidates’ selected were a number of teachers, and students. The data collected are perspective on both teachers and students in teaching and learning process objectives, classroom activity, supporting teaching materials. Student analysis was also carried out to determine students’ characteristic. It includes critical thinking level, their learning styles, worksheets preference. These will be used in designing PBI worksheets.

Curriculum analysis aims to analyze two supporting aspects, standard competency and basic competency. At this stage, writer reviews Indonesia K-13 curriculum for grade X in senior high school. It was conducted to gain information on topic limitation, learning objectives, and suitable PBI worksheets.

Concept analysis is the process of identifying materials discussed in teaching learning process. These materials are arranged systematically by linking a concept with other relevant concepts to form a new concept. This analysis aims to determine the content and subject needed so that students can achieve learning objective and critical thinking skill. Concept analysis includes creating a concept mapping. Information about what kind of materials will be taught is gathered through observation, documentation, and interviews.

| Tabel 1. Summary of Preliminary Research stage. |
|-----------------------------------------------|
| Analysis Activity | Analysis Focus |
| Needs Analysis   | 1. Have all mathematics objectives reflected in curriculum achieved in teaching learning process? |
|                  | 2. How is the teaching learning process so far? |
|                  | 3. Will the chosen material achieve learning objectives? |
| Student Analysis | 1. What are the students characteristic toward learning mathematics at grade X in SMA N 15 Padang? |
|                  | 2. What kind of worksheet do the students want? |
| Curriculum Analysis | 1. Which standard competencies and basic competencies are appropriate for PBI Worksheets? |
|                    | 2. Are the learning materials quite sufficient to achieve curriculum objectives? What should be included into consideration? |
|                    | 3. Do the learning materials arranged perfectly? What makes a good material arrangement? |
| Concept Analysis   | 1. What are the essential concepts, from curriculum analysis, needed |
3. Results And Discussion

This section covers the results of the preliminary analysis which was conducted at Grade X in SMA Negeri 15 Padang. The results of the preliminary analysis are divided into the results of the needs analysis, the results of student analysis, curriculum analysis, the result of concept analysis, and the results of existing teaching materials.

Needs analysis results: It was concluded that the students have low mathematical critical thinking skill and the learning goals were not achieved. There is no supporting learning process and appropriate students' worksheets that stimulate critical thinking skill. The current worksheet is not able to draw out and optimize students’ critical thinking skill. There is no specific worksheets that help teacher to achieve the goals. Thus, teachers need a teaching media that facilitate in developing students’ critical thinking skill.

A solution offered to solve the problem is by providing teaching media especially worksheets designed to achieve learning goals and objectives. Students' worksheets is one of the printed teaching materials that can help teachers to improve students' mathematical critical thinking skills. Students' worksheet provided must be based on student-centered approach and various activities develop students' mathematical critical thinking skills. Hence, PBI is one of the answers. Using PBI-based worksheet, students can hone their mathematical critical thinking skills. Moreover, the printed material must attract students' attention. In student interview, they said an interactive students' worksheet is needed so they would not be bored looking at the content. A colorful and well-organized worksheet is preferred.

Stand on Piaget's research, when the child hits 15 - 16 years old, the cognitive development should be at stage of formal operations. At the formal operation stage, they are able to solve problem, and think using abstract things. Concrete objects are no longer needed. In addition, Budiningsih states that the main visible development is they own logical and abstract thinking. In brief, teenagers around 15-16 years old are able to draw conclusion, interpret, develop hypothesis, and possess scientific thinking.

The second characteristic, based on interviews and observations conducted, clueless students tend to ask explanation from their peers. If they fail to understand the current lesson or topic, they prefer to ask the smartest student rather than raise their hand ask their teacher. They are not willing to directly confront the teacher and explain the detail of unsolved problem. There is no pressure when asking classmate and it helps better to understand the current lesson.

The third characteristic is the lack of concentration. Students are easily distracted and do not pay attention to teacher. Some were talking with their classmates. They do pay attention if the teacher scolds them yet it is not last for few minutes. The fourth characteristic is grouping. Students tend to do anything in small group rather than individually. For example, taking a break at school canteen, visiting places. It indicates that they feel much better when they are in group. Based on the characteristics found in the research, writer needs to develop PBI worksheet lead the students to do better in teaching learning process.

PBI worksheet is a learning material which will contain their unique characters especially those who love talking and attention deficit disorder students. Teaching and learning process using PBI worksheet will engage students in active learning. Furthermore, the students are taught how to solve math problem. Lastly, it also provide self-assignment for those who love working individually.

Curriculum Analysis Results: Curriculum analysis was conducted to review the 2013 curriculum in mathematics for senior high school. This analysis was completed to check the compatibility of Core Competencies (KI) Basic Competencies (KD), and Grade points average (GPA). Mathematics Teacher Association in Padang have come to agreement concerning the topic covered in the first semester for grade X students. (1) Absolute value equations and inequalities 2) Rational and Irrational inequalities, (3) Linear system with three variables (4) Linear inequalities in two variables (linear and quadratic inequalities) (5) Function. The result of curriculum analysis on mathematics Basic Competencies (KD) can be seen at Table 2.
Table 2. Standard competencies for Grade X in the first semester.

| Field of Knowledge                                                                 | Field of expertise                                                                 |
|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Interpret absolute value equation and inequalities with linear equation in one variable to another algebraic equation. | Solving problem related to absolute value equation and inequalities with linear equation in one variable |
| Explain and solve Rational and Irrational inequalities                              | Solving problem related to Rational and Irrational inequalities                      |
| Compile Linear system with three variables in contextual situation.                 | Solving contextual problem related to SPLTV                                         |
| Explain and solve problem about system of Linear inequalities in two variables (linear and quadratic inequalities) | Presenting and solving problem related to system of Linear inequalities in two variables (linear and quadratic inequalities) |
| Explain and determine linear functions, quadratic functions, and rational functions which include notation, origin, result, and symbolic expressions, as well as graphic sketches. | Analyzing each characteristic of graphs (intersection point, axis peak point, asymptote) and changes in the graph function due to transformations f2(x), 1/f(x), |f(x)| so on. |

Concept analysis serves to determine the material which will be taught in SMA N 15 Padang. After the contents were chosen, the next step are identifying concepts, writing detailed content, and arranging relevant material reflected in curriculum. Concept Analysis Results: Concept analysis aims to determine the content and mathematics subject needed in teaching media. The topic will relate and connect the whole concepts so that it can be arranged easily. Learning material can be used to choose, set, itemize and arrange relevant materials as reflected in curriculum.

Based on the regulation of the Indonesian Ministry of Education and Culture number 37 in 2018 [12], the mathematics topics for odd semester are (1) Absolute value equations and inequalities 2) Rational and Irrational inequalities, (3) Linear system with three variables (4) Linear inequalities in two variables (linear and quadratic inequalities) (5) Function.

4. Conclusion
Problem-based Instruction teaching media is used to enhance grade X students' critical thinking. In this research, the study is conducted until preliminary research stage. Plomp model, which consist of three stages: preliminary research, prototyping phase, and assessment phase, plays a major role in developing PBI teaching media. Using the developed PBI teaching media, writer expects it can improve students' motivation and inquisitive to study mathematics. Since it was designed to fulfill students' needs. The content provided in students' worksheets are also relevant and authentic problem.
The mathematics problem presented in the worksheets is solely to improve students' motivation, enthusiasm, classroom activities, and focus on finding the appropriate concept. Students should be more active in teaching learning process and implement the acquired lesson in their daily life or other subject.

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