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Prototype Teaching Mathematics in Improving Critical Thinking Ability of Senior High School Students

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***Abstract* — This study aimed was to describe the prototype teaching mathematics in improving critical thinking ability using problem based learning (PBL) for senior high school students. Researchers develop tools that include: (1) define (2) design (3) develop and (4) disseminate. The results of the definition phase is used to design a learning device, then draft the design is validated and tested to the students to see its effectiveness. The test device and dissemination limited classes used research subjects of students in Grade X SMAN 1 Percutseituan, Deli Serdang District, North Sumatera, Indonesia.**

The device was developed Learning Implementation Plan, Teacher's Book, Student's Book, Students Worksheets, and Study Achievement Test. The results of the implementation of the learning development that the device was valid, practical, and effective, which is characterized by (a) teaching materials developed met the content and construct validity (b) teaching materials developed easy for teachers and students to carry and fit for purpose and (c) learning outcomes of students after getting the learning-based teaching materials complete PBL approach. In conclusion (1) the prototype teaching mathematics in improving critical thinking ability using PBL for senior high school students produced practical devices (2) mathematics learning using PBL model is effective.

***Keywords* — Learning Instruments Development, Problem Based Learning Model, Students' Activity**

I. INTRODUCTION

Mathematical thinking skills are essential given to students ranging from the beginning of its development, especially when the child was in elementary school. Mathematical skills required so that learners can think logically. Mathematics needs to be mastered elementary school students to help digest the sciences in higher education (1). Mathematics as an important subject in modern society is useful in schools, workplaces, businesses and for personal decision-making. Mathematics is seen to be a language for everyday use whether in the market place, schools or even at home. It is fundamental to national prosperity in providing tools for understanding Science, Engineering, Technology and Economics (2). Efforts to develop the critical thinking skills of mathematics have become the main agenda in the curriculum of mathematics education worldwide (3). Critical thinking skills in mathematics is the process of critical thinking with related to knowledge of mathematics, mathematical reasoning and mathematical proofs in mathematical problem solving (4).

There is a variety of frameworks have been proposed for many years to capture the knowledge needed by teachers for teaching mathematics and the knowledge typically held by teachers of mathematics need to employ additional types of knowledge that are consequential for teaching the critical thinking skills for the students (5). A teacher that emphasizes reasoning, logic and validity gives their students access to mathematics as an effective way of practicing critical thinking. All students have the ability to enhance and expand their critical thinking when learning mathematics. Students can develop this ability when confronting mathematical problems, identifying possible solutions and evaluating and justifying their reasons for the results, thereby allowing students to become confident critical thinkers (6). The characteristics of students with creative thinking are the ones who have creative thinking ability in creating and finding new strategies and solutions for problems (7). Students would developed better mathematical thinking and perform better when the classroom creates an enabling environment in which students would have frequent opportunities to engage in more mathematical activities (8). It is included in the mathematics critical thinking is thinking that tested, questioned, connected, evaluated all aspects of the situation or a problem (4). Therefore, when teachers build learning environments that nurture and support students participation in reasoning and meaning-making, students themselves are also expected to offer explanations, an activity shown to contribute significantly to their learning. This, in turn, requires teachers to carefully analyze student productions, identify their promise—even when they might not be totally correct or accurate— and build on them to scaffold student thinking, while also keeping an eye on the mathematical goals of the lesson (5). In Indonesia, for example, one of the basic scientific thinking and its application plays an important role in the mastery of science and technology is mathematics. This means that the mastery of mathematics is necessary and important for the whole community, both the application and the patterns of thought. Therefore, the role of mathematics education is very important in order to develop the human resources of high quality (9). One of the learning models that use or association with Contextual Teaching and Learning (CTL) is problem-based learning (PBL), which is a model of learning that uses real-world problems as a context for students to learn through critical thinking and problem solving skills in order to acquire the knowledge and concepts are the essence of the subject matter (10). Learning module based on PBL is an effective method to develop critical thinking skills in mathematics on component of identification and interpretation information, information analysis and evaluation of

evidence and argument (11). Self-efficacy will influence the actions, effort, perseverance, flexibility in difference, and the realization of the objectives of this individual, so that self-efficacy related to one's ability often determines the outcome before the action occurs. A student with low self-efficacy which easily give up in the face of problems, tend to become stressed, depressed and have a narrow vision of how best to resolve the problem (12). By contrast, factors such as good teachers, good knowledge about the subject matter, good services provided by the teacher during his/her teaching, availability of textbooks and other learning facilities, student's attitude towards mathematics, teacher's motivation skills and the use of teaching and learning materials were the factors that support students' performance well in mathematics (13). When a group working toward a common goal, the students gain experience of working groups have the confidence and motivation higher than students who work alone. Low mathematics students' critical thinking skills of junior high school are closely related to the quality of teaching of mathematics teachers in the classroom (14). The critical thinking skills of mathematics students at SMA Negeri 3 Kendari in Indonesia is still low due to the learning of mathematics in the classroom monotonous, so that students feel bored in learning mathematics, students' passive learning, and students are not self-sufficient in constructing knowledge and untrained students develop thinking ability (15). A person with low self-efficacy which easily give up in the face of problems, tend to become stressed, depressed and have a narrow vision of how best to resolve the problem (16). This study aimed was to describe the prototype teaching mathematics in improving critical thinking ability using problem based learning (PBL) for senior high school students of Grade X SMAN 1 Percutseituan, Regency of Deli Serdang, North Sumatera, Indonesia.

II. Research Methodology

A learning device using PBL model in this study to produce Learning Implementation Plan (LIP), Teacher's Book (TB), Student's Book (SB), Students Worksheets (SW), and Study Achievement Test (SAT). Development of the device uses the development model of 4-D (17). Researchers develop tools that include: (1) define, (2) design, (3) develop, and (4) disseminate. This study is the firstly year research on a 2 year-planning for 2016-2017, conducted on all SMA schools throughout Province of Sumatera Utara, mainly to have an effective prototype instrument. For the first year test was conducted on students at Grade X SMA Negeri 01 Percutseituan, Regency of Deli Serdang, Indonesia.

The instruments used in this study were (1) validation sheet; (2) expert evaluation sheet and practicing about practical and effectiveness points of material; and (3) observation sheet. The data analyzed and led to respond the questions whether instrument and the lesson based approaching with learning based problem as developed has fulfilled criterion validity, practical, and effectiveness or not. The data analysis in developing this lesson uses a descriptive statistical analysis method. This study is declared successful if the instrument and the lesson as developed has fulfilled the criterion in validity, practical, and effective. Validity is fulfilled, if the lesson as developed has fulfilled validity in content and construct. It is practical fulfilled if the lesson as developed become easy to the teachers and students in implementation and conforms to the target. The effectiveness is fulfilled, if the performance as students following get the learning with the lesson based approach on the learning based problem is completely. The lesson based approach the learning based problem as developed is categorized effective if $\geq$ 80% of all subject in the test fulfilling completely rate of study.

III. Results and Discussion

Development of the mathematical model of learning PBL for senior high school preparation set out in two groups, i.e., the validity and practicality of the device.

A. The validity of device

Results of the device developed in this study were 5 types: (1) LIP, (2) TB, (3) SB, (4) SW and (5) SAT of Problem Solving Ability (Table 1). The process begins with the development of the initial draft (Draft I). The Draft I was further validated by experts (validators) and conducted in accordance with revisions to obtain input validator Draft II. Draft II devices are then tested. During the testing process, the revisions made in accordance with the demands of the field or external inputs in order to obtain the final draft (Draft III).

Table 1. Results Validation Tool Learning LIP, TB, SB, SW, and SAT

Devices	Validator					Average	Category
	I	II	III	IV	V		
LIP	4,25	4,52	4,30	4, 40	4,35	4,36	Very Good
TB	4,43	4,27	4,36	4,38	4,40	4,37	Very Good
SB	4,60	4,36	4,48	4,37	4,25	4,41	Very Good
SW	4,43	4,40	4,38	4,45,	4,32	4,40	Very Good
SAT	V/SR	V/SR	V/SR	V/SR	V/SR	-	-

Based on field observation on the instrument available on students at Grade X SMAN 1 Percutseituan, Regency of Deli Serdang, North Sumatera, Indonesia, indicated that SB hold did not present the matters that able train them in solving problem of comprising 22 questions. The SB did not present concept map so the material was not mapped clearly yet. In the learning process seen the teachers has just set the students as subject of learning there using a based learning model but the role of students is less maximal yet because the activity of students not led intensively yet. The activity of students should be more directive by providing SW on each learning, whereas for a longer was not provided SW on the learning. Due to highly important role of instrument in implementing a

good learning process, it is necessary to upgrade a better learning instrument that should be already tested its validity or effectiveness.

Validation experts conducted to see the validity of the content of the Draft I. The validators that performs validation consists of five people who are competent in mathematics research and education. The revisions of the learning device made based on the suggestion of to the draft validators, so that researchers find Draft II. Draft II was then tested to students Grade X SMAN 1 Percutseituan, Regency of Deli Serdang, North Sumatera, Indonesia.

After validation of the contents of the SAT by validators, further tests on Draft II SAT. The experiment was to analyze the problems with the test item validity, reliability, level of difficulty, and distinguishing features. In general, the results of developed learning instrument by the validation experts are as follows. (1) LIP have good criteria and can be used with Small Revision (SR), (2) TB has good criteria and can be used with SR, (3) SB have good criteria and can be used with SR; (4) SW have good criteria and can be used with SR, (5) problem-solving abilities SAT have valid (V) criteria and can be used with SR. The results of the study are valid development through defining stages define, design, and develop as follows.

A. Valid

Based to the score by validators in Table 1, the learning instruments as developed in the LIP with score validity of 4.36; TB with validity score of 4.37; SB with validity score 4.41; and SW with score of validity 4.40, and so that average validity of learning instrument is 4.41. It can be concluded that average validator gave a very good validity rate, this meant the learning instrument is V/reliable to use.

B. Practical

Practical value of the learning instruments was seen by : (1) valuation by experts and the practitioner (validators) that state out that learning instruments can be used and applied; (2) the result of observation in implementing the learning/capability of teacher to manage the learning is in good category namely about 4.29 on Test I and 4.01 on the Test II; 3) the students' activity as long as doing learning fulfilling criterion of tolerance time that has been decided and fulfill criterion of effectiveness limitation. For valuation by experts was obtained the results that the learning instruments can be used/applied with average score validation of learning instruments is 4.41, and on the results of observation in the learning average total observation is on very good category. For the activity of student, is obtained the result of output in Test I and Test II was on "effective" category. This means that learning instruments can be practical.

C. Effective

An effective learning instruments was measured by : (1) achievable the goal of learning or get completeness in learning by student classically namely in minimal 85% of students attending the learning is capable to achieve minimal score 75; (2) minimal 80% of many subjects in observation give a positive respond over the instruments and activity of the learning.

D. The practicality of device

Characteristics of students at Grade X SMAN 1 Percutseituan, Regency of Deli Serdang for study year 2016/2017 in the study covering the progress of cognitive, academic ability and study style of students. Students of the school were aged average 15-16 years old. If correlated to cognitive development referred to Piaget, these students are on a formal operational development phase. Means, on alike age the students has approached a maximal intellectual efficiency, due to shortage experiences so it limited one's knowledge and proficiency to exploit what one's know. The uses PBL model commenced presenting a problem as expected it could be experience for student to employ their knowledge known previously and it get a newly concept and more deeper. Based on the score list available in daily test obtained in Mathematics, noted 55% of students is classified completely while another 45% of students not completely with score average gained 79. Under an interviewed by the teacher of Mathematics obtained information that students have used in group study and adopted PBL model so the learning as designed not fully newly to the students. So, designing the instrument oriented PBL model is easier to understand and adopted in the learning activity. There are about 70.59% of students have a visual study style, 11.76% with audio and another 17.65% with kinesthetic style in study. Due to dominantly in visual style, meaning the students can immediately understand the information delivered under visual element. The students in this style is seemly effectively to do the learning by reading or drawing. Therefore, the learning instruments such as TB and SB or SW are designed in use the words easy to understand and with an attractive illustration.

The media in use to this study are a visual media with illustrative images and visual-aids. To chose these media for it is possibly to use immediately by student to simplify process of communication in the learning, still also supported with their style dominantly took visually. In choosing the format on the learning instrument is conformed to its principle, characteristics and steps in PBL model. In LIP model is listed the steps of learning followed a learning model based problem. The TB, SB or SW are provided in coloured with illustration and in attractive appearance so the students are attracted with and motivated to study. In addition, TB, SB and SW are presented consistently. On this stage resulted of a 14 LIP for 4 lesson material of study with 22 times-meeting, TB, SB, SW for each meeting, test of ability in solving problem. Alternative solution with score point in question and questionnaire self-stand in study. All the output of this design stage is stated Draft I. Draft I as resulted in this early design is validated by experts. The instrument of learning as output to this revision based any inputs as the validating shall be a learning instrument that has fulfilled criterion of valid stated Draft II. In general,our results can be applied to a wider audience with an average validity learning device was 4.36. Mastery learning was done on Test I reached 86% and Test II reached 91%. From the results of students questionnaire responses of the Test I and Test II resulted that more than 80% of students

responded positively on every aspect of the response to the learning tools developed. Based on tests of visual thinking ability in solving mathematical problems result that there is an increase in mathematical problem solving ability by 5 %. Average time percentage of student conducting time activities to hear/pay attention the explanation of teacher/friend was 25.06% on Test I and 26.73% on Test II by the time available on each meeting. Time percentage of this activity is in ideal time tolerated interval that has been decided previously. Average time percentage of students in activity to read/ to understand contextual matter in the SB/SW is 14.84% on test I and 12.68% on Test II. This percentage is also still on ideal time tolerated interval as decided. Average percentage of students' activity solving the problem/find the way and reply to the problem, namely 32.17% on Test I and 37.46% on Test II. Time percentage of this activity is also in ideal time tolerated interval as decided. Average percentage of students' activity to discuss/ask the friends or teacher, namely 18.66% on Test I and 14.64% on Test II. Time percentage of this activity is also in ideal time tolerated interval as decided. Average percentage of students' activity take conclusion a procedure or concept and present the performance, namely 7.18% on Test I and 7.16% on Test II. Time percentage of this activity is still in ideal time tolerated interval as decided. Whereas average time percentage of students conducting the activity is not relevant to the learning is 2.09% on Test I and 1.33% on Test II. This indicated that as long as activity of learning on each meeting always there are students conducting activities not relevant to the learning. This percentage, however is in ideal time tolerated interval that decided. In all, if average time percentage of students' activity referred to criterion achieving an ideal time percentage to activity of students that has been decided previously, it is concluded that time percentage of students' activity has already fulfilled criterion achieving an ideal time percentage as decided already.

Average percentage responds of students on both test is presented in Table 2. As can be seen that four of five aspects as asked get rising positive respond of students. For instance, interested aspect on the learning component got increasing by 87.3% to 93.25%. The average percentage respond of students on both test is arranged above 80%. The largest increasing occurred on the second aspect (up to date on the learning component) and the fifth (interested with appearance). This occurrence due to Draft III is remedial of Draft II, means several weakness on Draft II has been repaired based on the output of Test I.

Table 2. Average Percentage Respond of Students

Aspect	Test I (%)	Test II (%)
Interested with learning components	87,3	93,25
Up to date on learning components	80,6	90,35
Interested with further learning	91,4	92,1
Clearly of language	86,2	90,7
Seeing the appearance	84,8	90,1

Comparative the output of test ability in solving the problem by students is presented on Table 3. As can be seen that average ability in solving the problem by student on Test I is 2.51, whereas on Test II is 3.08. Percentage of students completely on Test I is 61.5% and not completely is noted 38.5%. Percentage completely as this rate 61.5% not fulfilled classical completely as decided namely ≥ 85%, whereas on Test II, percentage of students with completely is 87.1% and not completely is 17.9%. Percentage completely namely this rate 87.1% has fulfilled classical completely as decided.

Table 3. Comparative Ability in Solving the Problem

Remarks	Test I	Test II
Average (%)	2,51	3,08
Students is complete solving the problem (%)	61,5	87,1
Students is not complete solving the problem (%)	38,5	17,9

Summary of self-stand learning by students as obtained is presented on Table 4. As can be seen that average self-alone learning by students as on Test I is 46.32%, whereas on Test II is 48.26%. This average is gained by divided total score of all students with amount of students. Percentage students on Test I with self-alone learning category is noted the highest of 20.06%, in high is 24.68%, lower is 46.37% and the lowest 8.89%. Whereas, percentage students as in Test II with self-alone learning category is the highest is 22.15%, in high 32.45%, in low 38.21% and the lowest is 7.19%. On the last stage of development is obtained a field test with learning instrument in final. This final instrument comprising of LIP, SB, SW, test of ability to think critical and questionnaire of self-alone of learning by students.

Table 4. Summary Self-Alone Learning by Students

Remarks	Test I	Test II
Average	46,32	48,26
Students with the highest category (%)	20,06	22,15
Students with high category (%)	24,68	32,45
Students with low category (%)	46,37	38,21
Students with the lowest category (%)	8,89	7,19

The ability to think is one of the capital must be owned by the students in the face of developments in science and technology today. This capability is also a means to achieve the goal of education is to enable students to solve the problem of high-level stage. This is in accordance with previous study that the PBL can help students develop thinking skills, problem-solving skills as well as skills for independent learning and social skills (18). This study also supports another findings that PBL can enhance critical thinking skills in component of interpretation information (19). The results of this study also showed that learning modules based on PBL effectively helps students develop

critical thinking skills in mathematics to the component of information analysis. On non-routine problem solving in modules based on PBL, students try to explore issues of information and analysis of the information to plan strategy to solve the problem based on the information obtained to solve the problem (4). High schools students displayed attributes of critical thinking as they worked more diligently and analytically in their class (20). Our results were supported this findings that more than 80% of students responded positively on every aspect of the response to the learning tools developed. Based on tests of visual thinking ability in solving mathematical problems result that there is an increase in mathematical problem solving ability by 5%.

IV. Conclusion

Based on the process of development that has been proposed researchers obtained: (1) learning tools have been developed through a process of validation and otherwise comply with the content validity and construct validity were established by people who are competent in mathematics research and education, the learning tools developed in this research is valid, (2) the prototype teaching mathematics in improving critical thinking ability using PBL for senior high school students produced practical devices, (3) mathematics learning using *PBL* model is effective. The results of the development of this device is valid, practical, and effective. Hence learning device have been developed in this research need to be disseminated to the classes and other schools that have similar characteristics to obtain better learning and the device learning should be updated so there is always a refresher from time to time.

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