International Journal of Science and Applied Science: Conference Series P-ISSN: 2549-4635
Int. J. Sci. Appl. Sci.: Conf. Ser. Vol. 1 No. 1 (2017) 79-90 E-ISSN: 2549-4627
*International Conference on Science and Applied Science 2016* doi: 10.20961/ijsascs.v1i1.5124

# Development of problem-based learning model with metacognitive strategy to improve students' problem-solving ability

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**Abstract.** This research was conducted to: examine the problem solving ability of students in mathematics education FKIP UNS, (2) develop problem-based learning model with metacognitive strategy, (3) examine the effectiveness of problem-based learning model with metacognitive strategy. Three methods were used in this research: descriptive quantitative, research and development (RnD), and experimental method. The development method used 4-D model which consists of four phases: define, design, develop, and dessimenete. Experimental method was conducted to examine the effectiveness of learning model developed. The population in this research is all students of mathematics education FKIP UNS, while the sample used is students who took the Basics Matematics course. The data collections were used in this research: test, validation sheet, and observation sheet. Descriptive quantitative analysis technique was used to analyze the instrument development. Quantitative descriptive analysis was used to describe the validators' mark result for the learning instruments. Descriptive quantitative analysis was used to analyze the problem-solving ability test result that described by percentages. The efectiveness of model development was analyzed by T-test method. The results of this study showed that: (1) students' problem solving ability of mathematics education FKIP UNS particularly in non-algoritmic problems is still not good, but in algoritmic problems is good enough, (2) in the development of problem-based learning model with metacognitive strategy learning instruments, three instruments that qualify valid, practical, and effective there are: Learning Plan, Students' Activity Sheet, and Students' Teaching Material.

## 1. Introduction

In problem solving activity certainly there is a problem that must be solved. The problem is subjective for each person, meaning that a question can be a problem for someone if he/she challenging to solve the problem and doesn't has a spesific rules that can be used to solve it.

Models of learning that currently used now are still have limitations which train students' problem-solving skills only, such as problem-based learning model. That model still not train students' criticall thinking yet. That fact showed that problem solving requires not only problem-solving skills but also critical thinking ability. Therefore, the combination of problem solving teaching model and metacognitive strategy could improve students' problem solving and critical thinking skills that finally lead in increasing of problem solving ability.

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In order to solve the problems students need to master the material that have been studied previously and then use it in new situations. Eventough students have things or strategy that can be used to solve the problems, they are not surely able to solve the problem. For it, it's necessary to find the ways, method, or learning strategies that enable students to have ability in solving problems. Polya's heuristic strategies are summarized into four steps in solving problems, which are : understanding the problems, planing strategy/method, implementing the plan, and checking back the solutions. Polya's heuristic help the lecturers and students in solving a problem. However, that four steps cannot be simply implemented. Therefore, there must be other strategy so that problem solving skills can be mastered well by students.

When each of Polya's steps to solving problem examined, it required a situation that needs to be controlled by cognition. For example in the step of understanding the problems need to be controlled by cognition like in question of whether there is a sentence or vocabulary that confusing, whether ever the students found the problem before, wheather the students can raise concern with another sentence or by using a symbol or image that easy to understand. For these examples, it is necessary to involve cognitive control at every steps of problem solving. The question from these examples is a way to increase self-awareness of thinking and learning. If this awareness exist, student can control the mind. The intended manner is called metacognitive strategies.

Besides of involving the metacognitive in steps to solve the problems, it can be involved in the syntax of learning model. That will lead to obtained the learning result which makes students become more critical. In turn, the students' problem solving ability to be increased.

In connection with efforts to improve the students' problem solving ability, problem based learning is be appropiate for used correspond with completing math problems. One of the principles of problem based learning is focus in developing students' critical thinking and reasoning skill so that will further develop the students' creativity. The principle of metacognitive strategy is to develop critical skill.

The main principal of problem-based learning is to form of students' activity through authentic and meaningful problem situations as a stepping stone towards the discovery and inquiry. The purpose of problem-based learning is help students to learn the material and develop problem solving skills through real problems in daily life (Arend, 1997).

The problem based learning phase has a character to set the students in pairs or small groups to investigate problems associated with daily life problem. According to Arends, R I (1997), problem-based learning phases are as follows:

- Determining the goals

Problem-based learning at least have a purpose to improve the intellectual and capabilities in investigation, increase the understanding about rules and helps students to become good learners.

- Designing the proper problems situation

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Lecturers are expected to choose a problem situation that could motivate the students to discover the solution. Therefore, the good problem situation are authentic (in the form of puzzles), meaningful for students, and consistent with the objectives of curriculum.

- Organizing the learning resources

Students should be provided with learning resources as complete as possible in order to optimalize the learning, including provision of laboratories, libraries and others.

- Bringing the student into problems

At the beginning of problem-based learning, lecturer explain the purpose of learning, so that lead the students to figure out what should be done. Therefore, lecturer should explain the procedure of learning implementation.

- Organizing the students to learn

Problem based learning not only improves students' problem solving skill, but also offers skills in teamwork development. Therefore, the learning can use the form of team study and cooperative planning. At that time, lecturer can give student some general directions for solving problems, but lecturer is not supposed to interverned the student so that ideas possessed by students are not developed.

- Analyzing and evaluate the problem solving process

At this stage the lecturer asked the students to reconstruct their thought and activities during the phases of learning. The students' answer for the questions can be analized and evaluated whether they are able to improve their intelectual inquiry and problem solving or not.

John Flavell (1976) is the first who introduced the term of metacognition as "a person's knowledge about the cognitive processes". Metacognition is an ability of an individual as if standing outside his/her head and tried to reflect on how he/she think or cognitive processes that are performed. According to Matlin (1994), metacognition is a knowledge, awareness, and control to against our cognitive processes. Further, Matlin said that metacognition is very important in helping us to set the environment and to select strategies improving our cognitive abilities. So the metacognition is a knowledge, awareness, control and management with the use of our minds to our cognitive processes, so as if we stood outside our heads and try to reflect on the way we think in cognitive processes.

Metacognitive strategies or metacognitive setting is a sequential process that can be used to control the activity of cognition and ensure the cognition objectives (such as a text understanding) has been reached. This process helps us to regulate our learning in planning and monitoring the activity of cognition, such as checking the results of learning activities (Brown, 1987). Self-question is general metacognition form of a strategy to monitor the understanding. Self-question from metacognitive strategies is used to ensure that the cognitive objectives can be achieved (Livingstone, 1997).

Metacognitive strategy refers on a way to raise awareness about the thinking process and learning that are applicable. If this awareness exists, someone can control the mind by designing, monitoring and assessing what they have been learned (http://myschoolnet.ppk.kpm.my/ bhnpnp / modules / bcb8.pdf). Therefore, the use of metacognitive strategies could control students' learning activities through the

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following process: (i) Designing what will be learned (ii) Monitoring the progress of the self learning (iii) Assessing what have been learned.

From the explanation above, we can made a restrictions on metacognitive strategy is a way to raise awareness about the thinking and learning process that applied to control the activity of cognition and to ensure an cognition objectives have been achieved. If this awareness exists, someone can control the mind by designing, monitoring and assessing what they have been learned.

According to Nur (1999), students can be taught some strategies to assess their own understanding, calculate how much time spent to learn something, choose an effective plan to study or solve problems. Furthermore, Paris (1987) and King (1992) found that students' mastery could be better if they are taught to ask themselves the questions about who, what, where, and how they read.

The opinion above suggests that the thinking skills including metacognition can be programmed in a learning activity. The writings on http://myschoolnet.ppk.kpm.my/bhn-pnp/modul/bcb8.pdf explains that metacognitive should not be taught as a subject or as a separate strategy. Metacognition should be taught by infusion or integrated in learning activities. By applying metacognition in every stage of learning, the skills of metacognition spontaneously and unwittingly could be fostered. Students can be taught metacognitive strategies to help them to solve the problem in individual or in a group. From these explanations can be inferred that integrating the metacognitive strategies in learning using problem-based learning model is the way to taught metacognition strategies by infusion.

Here are presented the syntax of problem-based learning with metacognitive strategies:

**Table 1.** Syntax of problem-based learning model with metacognitive strategies

| Stage | Lecturer activity | Student activity |
|---|---|---|
| Orientating students to the problems | - Giving information about the learning goals<br>- Creating the classroom environment that allows an ideas exchange.<br>- Directing a question or problem<br>- Encouraging learners to express ideas together | - Receiving information about the learning goals<br>- Ready for participating in learning activities with PBI model<br>- Understanding the question or problem<br>- Comunicating the ideas openly |
| | **The use of metacognitive strategies:**<br>*Help students to aware of themself about whether the problem can be understood, whether the problem is meaningful to theirs or whether they have a thought to complete it.* | *Students ask to himself: whether the issue raised can be understood, whether the problem is meaningful to theirs or whether they have a thought to complete it.* |

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| | | |
|---|---|---|
| Organizing students to learn | Assist the student todefine and organize the learning task related to the issue. | - Defining and organizing the learning task related to the issue |
| | **The use of metacognitive strategies:**<br>*Help students to aware of themself about what possessed knowledge related to the problem to be solved, whether knowledge deemed sufficient. With the answer to the question of how to resolve the issue? Is it necessary to work in collaboration with other friends?* | *Students ask to himself: what knowledge will be used in solving the problem? Does that knowledge sufficient enough to solve the problem? Wheter they need to work together to other friends?* |
| Guiding the investigation in independent or group work | Encouraging the students in collecting the appropriate information to encourage cooperation and completion of tasks.<br>Provide convenient situation in solving problems | - colecting the appropriate information<br>- developing cooperation in the completing the task |
| | **The use of metacognitive strategies:**<br>*Help students to realize the situation himself about whether learning resources (eg, books, props) that can be used in solving a problem is enough, what should be done so that the activities of the group become optimal to solve the problem. When has drafted a settlement, whether the design of strategy is good enough.* | *Students ask themself: Is learning resources that can be used to solve the problem is enough? what should be done so that the activities of the group become optimal? whether the strategy to solve problem is good enough?* |
| Developing and presenting the work | Guiding the students to presenting their work. | - working s student activity sheet in individual or group<br>- presenting the result of work |
| | **The use of metacognitive strategies:**<br>*Help the students to aware of themself on whether the MFI can be used to solve the problem and in accordance with the design have made?* | *Students asked to themself: whether the MFI can be used to solve the problem and in accordance with the design have made? Are there any difficulties in doing MFI, where this part is difficult,* |

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| | | |
|---|---|---|
| | *Are there any difficulties in doing MFI, where this part is difficult, why is it difficult? How to overcome the difficulties? How to present the work well? Are they experiencing difficulty in presenting the work? How to overcome the difficulties?* | *why is it difficult? How to overcome the difficulties? How to present the work well? Are they experiencing difficulty in presenting the work? How to overcome the difficulties?* |
| Analyzing and evaluating the problem solving process | Help the students to compose reflection or evaluation of the processes used. | Compose the reflection and evaluation of the processes used. |
| | **The use of metacognitive strategies:** *Help students to aware of themself how to perform a reflection or evaluation of the processes use. Whiche part that they need to do reflection or evaluation? How to? What's the Follow-up after reflection and evaluation?* | Students *asked to themself: howto perform a reflection or evaluation of the processes used? Whiche part that they need to do reflection or evaluation? How to?* What's the *Follow-up after reflection and evaluation?* |

Based on the syntax above, the formulation of the problem in this study is: How the development result of problem-based learning model with metacognitive strategies can enhance the students' problem solving ability effectively and efficiently?

## 2. Research Methods

This study used descriptive quantitative and research & development method. The development research methods used 4-D model which consists of four phases, there are: define, design, develop and dessimenete (Thiagarajan, 1974: 5). Define is the phase of problem analysis that followed by determine the terms of learning. Determination of this phase is done by analyzing the students' problem solving ability. Design is the phase to plan a model and a learning instruments (prototype). Develop is the phase to modify the model and learning instruments through expert validation and test. Dessimenete stage is the stage of trials on actual classes to obtain the final models and learning instruments. This phase is performed experimental studies to determine whether the learning model that was developed have a positive impact on student learning outcomes.

To obtain the necessary data, this study used a test technique. The test that used for examine the ability of problem solving, the validation sheet, the student response sheet about the instruments and the implementation of learning.

Data analysis technique in the development of learning instruments that used is quantitative descriptive analysis technique. Quantitative descriptive analysis is used to describe the results of learning instruments assessment by validator. To analyze the

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problem solving ability data, this study used quantitative descriptive analysis techniques which is described by percentages.

## 3. Ressults and Discussion

### Research Results

The problem solving ablity test result is described below:

**Table 2.** Description of the test result

| Category | Algoritmic problems | Non algoritmik problems | Total Score |
|---|---|---|---|
| The Higest Score | 50 | 45 | 70 |
| The Lowest Score | 20 | 5 | 35 |
| Score Average | 37,770 | 18,851 | 56,662 |
| Standart Deviation | 8,686 | 8,422 | 10,472 |

Table 3. Summary of Problem Solving Abilities Category

| - Subject Category | | |
|---|---|---|
| Low | Medium | High |
| 12,16 % | 83,78 % | 0,04 % |

The description is based on the answer: low (score < 25), medium (25 ≤ score < 40) and good (score ≥ 40), can be presented as follows:

**Table 4.** Answer Result on Algoritmic Problems

| Subject Category | Answer Result | | |
|---|---|---|---|
| | Low | Medium | Good |
| - **Low** | 22,22 % | 77,78 % | 0 % |
| Medium | 0,02 % | 41,92 % | 58,06 % |
| High | 0 % | 33,33 % | 66,67 % |

**Table 5.** Answer Result on Non Algoritmic Problems

| Subject Category | - Answer Result | | |
|---|---|---|---|
| | - Low | Medium | Good |
| - **Low** | 100 % | 0 % | 0 % |
| Medium | 74,21 % | 22,58 % | 3,23 % |
| High | 0 % | 66,67 % | 33,33 % |

The learning instruments that is developed in this study were (i) Learning Plan (RPP), (ii) Student Teaching Materials (MAM) and (iii) Student Activity Sheet (MFI). The development of learning instruments used 4-D model which consists of four phases: define, design, develop and dessimenete. The results of each stage were descibed bellow:

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### *3.1. Define*

Based on the interviews with some of the mathematics lecturers and observation of the researchers, the teaching that has been done by lecturers still less in involving students. Lecturers using conventional learning patterns, which explain a concept or procedure with little question and answer, give examples of the questions and provide a practice task which must be done in the group that not all students come to solve the problems but only students who are considered proficient in the group who solve on the problems. This resulted in students not involved in learning optimally, in mentally, physically and socially.

#### *3.1.1. Students' Analysis*

This analysis was conducted to examine the students' characteristics on problem solving ability. Based on the problem-solving ability test results, students' problem-solving ability in general is still relatively low especially in the non-algorithmic problems. While on algorithmic problems, the ability of students is quite good.

#### *3.1.2. Material Analysis*

The goals of material analysis is to identify the main parts of the logic material to be learned by student. Based on the analysis of learning materials, then this study set it as follows:
1) There is no material prerequisites that must be understood before studying logic is : (1) proposition (2) logic composition (3) logic algebra (4) conclusion.
2) The learning activities are divided into three sessions with 150 minutes (3 session of lessons) of each meeting.

#### *3.1.3. Task Analysis*

Based on the analysis of the logic subject, the tasks or skills that should be possessed by students after studying this subject as follows:

1.) Giving examples in various forms of propositions.
2.) Understanding some of the logic composition.
3.) Understanding the logic laws.
4.) Using the logic laws to proof that a expression is tautology, contradiction or contingency.

### *3.2. Design*

The results of each activity at the design phases are as follows.

a. Selected Media Result.

Media is needed in the implementation of learning include: Learning Plan (RPP), Student Teaching Materials (MAM), and Student Worksheet (MFI).

b. Selected Format Result

Selected format for learning instruments correspond to the principles, characteristics, and learning steps. In the lesson plan listed standards of competence, basic competence,

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the indicators, the material prerequisites, learning materials and management. The learning activities consist of preliminary activities, main activities and final activities. The learning approach used is problem-based learning with metacognitive strategies.

c. Preliminary Design Result

This stage was produced a preliminary draft of Learning Plan (RPP) for 4 meetings, Students Teaching Materials (MAM), and Students Worksheet (MFI) for each meeting. All of the results in design stage is called first draft. In general, the results of the initial design are as follows.

1) Learning Plan (RPP)

Learning Plan (RPP) consists of 4 sets for 4 meetings. The lesson plan outlines is described as follows.

a) Learning Plan 1 (RPP 1)

The time allocation is 3 x 50 minutes which is discuss about the proposition and logic conjunctions materials. Indicators of achievement be described as follows.

(1)Giving examples of various forms propositions

(2)Understanding the logic conjunctions

b) Learning Plan 2 (RPP 2)

The time allocation is 3 x 50 minutes which isdiscuss about the logic algebra materials. Indicators of achievement be described as follows.

(1)Understanding in the use of logic laws

c) Learning Plan 3 (RPP 3)

The time allocation is 3 x 50 minutes which is discuss about the tautology, contradiction and contingency materials. Indicators of achievement be described as follows.

(1) using the logic laws to prove that the expression is a tautology, contradiction or contingency.

(2)Students' Activity Sheet (LKM)

LKM (worksheet) that was developed consist of authentic problems and include the developed questions.

(3) Students' Teaching Materials (MAM)

Students' Teaching Materials contains the description of the material presented in herarkhis and systematic. The teaching material consist of four parts: an example in the various forms of propositions.

### *3.3. Develope*

#### *3.3.1. Learning Plan Validation Results*

The results of the learning plan validation (RPP) showed that three validator marking is that it can be used with a revised. Suggestions for revision of four-validator, which are summarized as follows: the problem is too difficult and take a long time to solve it, the learning activities are still dominated by the lecturer, learning concept still not using the given problem at the beginning of learning, the concept should be constructed by students, while lecturers become the facilitators.

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### *3.3.2. Learning Materials Validation Result*

The teaching materials validation by three validators resulted that learning materials can be used with the revision. Suggested revisions by three validators can be summarized as follows: the material is too broad, teaching materials look less attractive.

### *3.3.3. Students' Activity Sheet Validation Result*

The students' activity sheets validation resulted that student activity sheets can be used with the revision. Suggested revisions by three validators can be summarized as follows: in each activity there are too many problems posed, the problem is too difficult for the students, the time required in doing LKS is defficient.

Based on the validation results of all three types of learning instruments concluded that the learning instruments can be tested with the revisions

## *3.4. Trial Phase of Learning Instruments*

The trial phase objective is to improve various learning. It has been done in 3 meetings, that correspond with the implementation plan. In this activity, the researchers only provide guidance to lecturers who will carry out the learning activity.

### *3.4.1. The lecturers ability to manage learning assesment result*

The ability of lecturer to manage learning at each meetings reached the category of "good and very good", which is in interval scale: 3,40 < TKG < 4,20 dan 4,20<TKG <5.

### *3.4.2. The observation of students during the learning activity*

Students' activitiy was observed by an observer. Observations were made during the learning process and the results can be analyzed that the activity average of the students were in the limits the effectiveness of learning criteria as described in Chapter III, since in general the student activities percentage is in the criteria limits the effectiveness of learning, the learning instruments not been revised based on the results of student activities observation.

### *3.4.3. Students' questionnaire responses result*

From the questionnaire responses of students who filled out by 36 students obtained that students respond to all aspects was above 80%. This means that every aspect of positive response by students so that learning instruments don't need a revisions based on student responses.

Based on the valid criteria, produced the problem-based learning with metacognitive strategies learning instruments that valid for the logic subject matter. Learning instruments produced include Learning Plan (RPP), Students Teaching Materials (MAS) and the Student Worksheet (LKS). The result of learning instrumens after that referred to become final learning instrumens.

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### Discussion

From the description about the data presented in Table 2, it can be interpreted that the problem solving ability of students is still low. Students who have problem solving ability in the high category is very low less than 1% (0.04%). Most students only belong in the medium category.

When viewed from the subjects category based on problem solving ability, namely high, medium and low, the students which are in the low category were no able to finish either algorithmic problems. Students which in medium and high categories have been able to complete algorithmic problems reached more than 50%. While in non algorithmic problems able to finish problems properly is better than the category of low, medium and high. Even the low category students can be said to have the least ability to resolve non-algorithmic problems. The medium category student being capable to solving a non-algorithmic problems properly was very small, ie less than 5%. Most of the students in lower and medium category in completing non-algorithmic problems, ie almost 75%. While in high category there are very few student who have the ability to finish non-algorithmic problems, less than 50%.

Based on the discussion above we can infer that students are quite good in completing algorithmic problems, but very low in non-algorithmic problems. This is understandable because of the learning habits tend to be mechanistic and more giving algorithmic problems (procedures).

Learning instruments that is developed in this study were (i) Lesson Plan (RPP) with problem-based learning, (ii) Student Teaching Materials and (iii) Student Activity Sheet (LKS). On the development of learning tools used 4-D model which consists of four phases: define, design, develop and dessimenete. The results of the four stages of instruments development acquired at the instruments of problem based learning model with metacognitive strategies are valid.

## 4. CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

The conclusions of this study are: (1) Students' problem solving ability in general is still relatively low, especially on non-algorithmic problems. But on algorithmic problems, the ability of students can be quite good, (2) on the development of problem-based learning with metacognitive strategies, there are three types of devices: Learning Programme Plan (LPP), Student Activity Sheet (SAS) and Student Teaching Materials (STM).

### Recommendations

From the results and conclusions of this research, it can be recommendated as follows: (1) The results showed that the problem solving ability of students on a non algorithmic problems still low, it is recommended to the lecturer or other educators, should avoid learning that tend to be mechanistic which only teach how to use the way or procedures

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but more emphasis on learning that more conceptual with using many questions. Lecturer should give a lot of problems that are not procedural but rather on questions that included an open problem , (2) the problem-based learning with metacognitive strategies instruments that has been developed can be used by lecturer to develop it in different situation, classes and topics.

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