

# Fostering Student's Higher-order Thinking Skill Through Problem-based Learning in Calculus

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**Abstract**—Problem-based Learning (PBL) is one of recommended learning models in implementation of curriculum 2013. PBL provides opportunities for students to construct knowledge, and enhance their thinking skills through the filling of a problem as the starting point of learning process. Problems in PBL requires students to regain access to prior knowledge that lead students to think deeply. Thinking is infused in PBL when students plan, generate hypothesis, employ multiple perspective, and work through facts and ideas systematically. Problem resolution also involves logical and critical analysis, use analogies and divergent thinking, and creative integration and synthesis. Thinking Activities are needed by students, especially for understanding difficult math materials. One of math material that need student's thinking is calculus. It consist of limit, derivative, and integral of function. Not only a lot of students that have difficulties to learn calculus, but also teachers. They have difficulties in how to teach this material. Therefore, PBL is the most suitable method that can be an alternative to teach calculus. In conclusion, PBL activities in the classroom will foster student's higher-order thinking skill.

**Keywords:** *fostering, higher-order thinking skill, problem-based learning, problem, calculus*

## I. INTRODUCTION

Inovation in education still held in every year to improve quality of learning activity. Improvement of learning quality purposed to solve all problems that faced, include Mathematics learning problems. One of inovation in education that had been done by government is evaluation of curriculum.

In 2013, Indonesian government decide new curriculum named curriculum 2013 for elementary and secondary school. Implementation of that curriculum can be seen in learning procces in the classroom. Learning procces of schools holds in interactive, inspirative, interesting, challenging, and motivated students to be active and give oppurtunities for their innovation,creativity, indepedece through their talent, interest, physically and psychology [11]. Paradigm that used in learning procces is constructivism [16]. So that learning models that used in learning procces based on constructivism paradigm.

Implementation of curriculum 2013 still has many problems. Most of teachers in indonesia have difficulties in imeplementation curriculum 2013 [16]. The big problem that face is the lack of teacher understanding about the new curriculum [17]. In the other hand, learning quality in the classroom effects in improvement of student's thinking skill. Teacher as a designer must provide learning atmosphere that can be support improvement of sudents' thinking skill. Ideally, all students are provided high-quality instruction that offer the oppportunity to learn the knowledge and skill [7]. In constructivist class, a teacher does not teach how to answer the questions, but presentated problem and encouraging students to find out their strategy in solve the problems.

According to Vygotsky, thinking skill growth from lower to high level. Learning material should be used as a tool to train student's thinking skill, not as a purpose [19]. Beside that, learning not only as rehearsing information and formulas/equation, but also how to use that information and knowledge to sharp the thinking skill. The learning environment should encourage students to engage in higher-order thinking activities [19]. Teachers need to move away from an over-emphasis on content mastery and adopt pedagogies that enable the development of thinking processes [15]. To foster student's higher-level thinking, teachers must possess not only in-depth subject matter knowledge in the field they are specializing in, but also good pedagogical knowledge on how to develop student's higher-order thinking –

both in the context of the subject matter they are dealing with and as a general skill [2]. Pedagogical knowledge include learning models based on the purpose in curriculum.

One of learning model that recommended in implementation of curriculum 2013 is Problem-based learning [16]; [10]. Problem-based learning (PBL) is learning that use problem as starting point of learning proses [21]. "Problem-based learning has been shown to actively engage students in relevant learning experiences" [1]. Student's activities in problems-based learning, can help them to build their thinking skills and problem solving. effort to encourage student's higher-order thinking skill that have positive effect in increasing motivation and achievement [4]. In short, problems that pose in learning process can help students to construct their knowledge and find out the concept through problem solving process.

Students need thinking activities to understanding the difficult learning material in mathematics. One of the difficult material is calculus [20]; [3]. Not only a lot of students that have difficulties to learn calculus, but also teachers. They have difficulties in how to teach this material. To solve the problems, learning by using PBL model can be used as an alternative. Many finding of researches was suggested teachers to use PBL in learning mathematics to improve student's thinking skill. PBL in calculus course improve student's critical thinking, evaluative and judgment/making decision [13]; [9]. Therefore, adopting PBL method in learning process, teacher can create a number of creative thinkers, critical decision makers, problem solvers which is very much needed for the competitive world.

## II. LITERATURE REVIEW

### A. *Problem-based Learning*

Problem-based learning (PBL) is a student-centered approach that organizes curriculum and instruction around carefully crafted "ill-structured" and real-world problem situations [1]. PBL focus on problem use as starting point in learning process [21]. Problem-based instruction describes a learning environment where problems drive the learning. That is, learning begins with a problem to be solved, and the problem is posed such a way that students need to gain new knowledge and skill before they can solve the problem [18]. PBL is recognized as a progressive active-learning and learner-centered approach where unstructured problems (real-world or simulated complex problems) are used as a starting point and anchor for the learning process [21]. It can be conclude that problem-based learning (PBL) is learning model that student-centered and use contextual, complex, ill-structured problems as starting point learning process. PBL process not only oriented in finding solution of the problems, but also problem solving process it self and help them to find the concept.

PBL activities in the classroom involve design of problems and organize of students. Every step of PBL required students be active in that activity. Problem-based learning (PBL) in the classroom includes the following steps. Tan [22] suggest five steps: (1) meeting the problem; (2) problem analysis and learning issues; (3) discovery and reporting; (4) solution presentation and reflection; and (5) overview integration and evaluation. Arends and Kilcher [1] suggest five steps: (1) orient students to the problem; (2) organize students for study; (3) assist independent and group; (4) develop and present artifacts and exhibits; and (5) analyze and evaluate the solving process. Beside that, Eggen and Kauchak [6] suggest four steps: (1) review and present the problems; (2) define strategy; (3) implement the strategy; and (4) examine and evaluate solution. According to some opinion above, we can see that PBL activities in the classroom include: (1) present the problems; (2) organize students for study; (3) identification and formulation the problems; (4) investigate and problem solving; (5) solution presentation presentasi; and (6) evaluate and making conclusion.

Teacher's roles in PBL are design the problems, facilitate, and mediate students in learning process. Teachers do not give subject material but motivated and facilitated students by giving problems. In problem-based learning, complex and real-world problems are used to motivate students to identify and research the concepts and principles they need to know to work through those problems [5]. In PBL, students are given the opportunity to find knowledge for themselves and to deliberate with other. They then refine and restructure their own knowledge with new knowledge and experiences. Therefore PBL in the classroom is not only about infusing problems into the class but also about creating opportunities for students to construct knowledge themselves. Fig. 1 shows shift of learning paradigm from traditional model that focused on learning material to be learning that focused on problems by using problem-based learning (PBL).

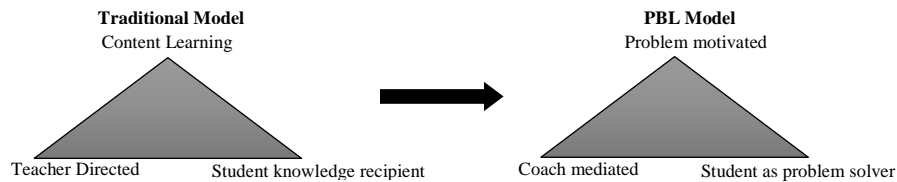


FIGURE 1. SHIFT OF LEARNING PARADIGM FROM TRADITIONAL TO BE PBL

Paradigm that used in PBL appropriate with curriculum 2013. There are 14 points suggested in learning process based on this curriculum. Several of learning process that suggest in that curriculum accommodate in PBL. there are learning that from students be informed about concept, to be students to find out, from teacher as the only one learning source to be learning with many sources, from learning based content to be learning based competence, and from learning that suggest one solution/answer to be multi solution [11].

*B. Facilitating Higher-order Thinking Skill in PBL Process*

Here are techniques to foster student’s higher-order thinking skills through learning activities in the classroom. These techniques are related with teaching strategies. Musfiqi and Jailani advise that to improve the higher-order thinking skills (HOTS) of students, the teacher’s role as facilitator should be noticed [14]. Moreover, Protheroe [8] suggested that a mathematics classroom must do the following things to achieve an effective environment for higher-order thinking: (1) actively engage in doing mathematics; (2) solve challenging problems; (3) make interdisciplinary connections; (4) share mathematical ideas; (5) use multiple representations to communicate mathematical ideas; (6) use manipulative and other tools. Beside that, Upon studying the effects of varying instruction for high school math and science students, Miri, David, and Uri [12] proposed the following three teaching strategies for generating higher-order thinking skills: (1) present real-world cases–encourage students to cope with relevant situations; (2) direct class discussions related to a concept/phenomenon or a problem–encourage students to ask questions and present their own solutions; and (3) guide short inquiry-type experiments in groups–encourage students to learn in cooperation.

Thinking is infused in PBL when students plan, generate hypothesis, employ multiple perspective, and work through facts and ideas systematically. Problem resolution also involves logical and critical analysis, use analogies and divergent thinking, and creative integration and synthesis. One of strategy that can be used by teachers in PBL is the questioning method. Questions aim to help students through each step in the PBL activity. Many researchers have proposed using probing techniques or questioning methods to enhance thinking in students. Asking higher-order questions has values in helping students to develop their thinking skills Wetzel [8] proposes using the following examples as questions that probe the individual toward higher understanding: (1) what additional information do you need to solve the problem?; (2) how does the data relate to your findings?; (3) how does the evidence support your conclusions?; (4) what would you need to do to determine if this solution is true?; (5) how can you compare this with other problems?. These questions can be given from the beginning until the end of learning process. Table 1 show the list of the questions that can be used to facilitate student’s thinking skill in PBL activities.

TABLE 1. QUESTIONS LIST TO FACILITATE HOTS IN PBL ACTIVITIES

PBL Activities	Question
Identification and formulation the problems	<ul style="list-style-type: none"> <li>• What the meaning of limit on that problem?</li> <li>• What being approximate?</li> <li>• Is the value of <math>f(x)</math> around <math>x = c</math> can be define?</li> <li>• Why the value of <math>f(x)</math> at <math>x = c</math> does not exist?</li> <li>• What are the differences tangent line and secant line?</li> <li>• What additional information do you need to solve the problem?</li> </ul>
Investigate and problem solving	<ul style="list-style-type: none"> <li>• Is the limit of function can be define by using method...?</li> <li>• Why limit of that function can not be define by method...?</li> <li>• Is the problem can be solving by using method...?</li> <li>• Is the other ways more effective?</li> </ul>
Evaluate and making conclusion	<ul style="list-style-type: none"> <li>• How about the limit of function... if the value of <math>x</math> is change with approximate with...?</li> <li>• Write two or more problem that can be define by using our concepts.</li> <li>• What would you need to do to determine if this solution is true?</li> <li>• How can you compare this with other problems?</li> </ul>

### III. CONCLUSION

Based on the description above, it can be concluded that PBL activities in learning calculus class will foster student's higher-order thinking skill. Beside that, to be more effective in PBL activities, teacher's role as a facilitator should be noticed. In addition, the use of PBL in teaching calculus must be supported with these kinds of problems presented in each of the learning process.

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