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Heterogeneity of problem-based learning outcomes for improving mathematical competence: A systematic literature review

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Abstract. This study aims to analyze the impact of the application of Problem Based Learning (PBL) on improving the mathematical competence of elementary, junior high and high school students. The method used is a Systematic Literature Review (SLR). The sample consisted of 117 experimental research results on the effect of PBL on improving mathematical understanding, problem-solving, creative thinking skills, or mathematical literacy. The research was conducted in all related classes. Samples were taken from indexed journals published in the 2010-2020 period. The key question of this research is how to describe the effect of PBL on students' mathematical competence, in terms of year of study, study level, duration of experiment, and sample size. Through SLR method it was found that there was an increase in the number of studies over ten years. Based on the study level research on junior high school students was more dominant, based on the duration of experiment, more research was conducted in junior high schools, and based on the sample size research was mostly conducted in classes with 30 or more subjects.

1. Introduction

The 2013 mathematics curriculum explicitly requires teachers to implement student-centered active learning. All students are expected to understand the material in-depth and have high-level mathematical skills, including problem-solving, creative thinking, and mathematical literacy [1]. Developing a deep mathematical understanding is the goal of learning mathematics [2]. Through deep mathematical understanding, it allows someone to solve problems better. NCTM [2] states that problem-solving is the essence of mathematics. So that problem solving has an essential role in learning mathematics [3]. Problem-solving can be a process where students can make decisions about the problems to be faced [4]. Problem-solving is called an attempt to identify a problem that exists. in daily life. Understand mathematics becomes the foundation for achieving high-level skills, which all educational institutions currently emphasize. High-order thinking and understanding abilities are seen as being able to equip students to face change and solve daily problems that are increasingly complex, so they need to be prepared from the start [5-7].

Although a person's creative thinking process is characterized as a different process for each person it has agreed-upon stages of the process including preparation, incubation, illumination, and verification [8]. Literacy is one of the 'high-level' thinking skills included in critical arithmetic, which is in mathematical literacy [9]. Mathematical literacy involves mathematics knowledge in a broad sense and

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is not limited to applying aspects of numbers and calculations to mathematics. In OECD / PISA, mathematical literacy is related to students' ability to analyze, reason, and communicate ideas effectively when students convey, formulate, solve, and interpret mathematics in various situations [9, 10].

Educators have responded to the importance of students achieving higher order thinking abilities and skills through various studies in learning practice in schools. One thing that has been done a lot is by implementing a problem-based learning model (PBL). PBL aims to stimulate students to learn actively, through problems students are challenged to explore curiosity and curiosity, develop higher-order thinking, through active student discussion on problems, hypothesize, and solve problems [4, 6, 11-15]. The reliability of PBL in improving critical and creative thinking skills can be seen from the results of several primary studies, especially when compared to conventional learning [16-21].

The results of individual studies do not completely guarantee that PBL has any promising effectiveness in developing and improving high-level mathematical skills. There is heterogeneity among these studies results, and it is possible that some studies could potentially be biased. It seems that a comprehensive review is needed. How to describe the PBL implementation in mathematics teaching and learning. For this reason, research was carried out in the form of a systematic review of the implementation of PBL in increasing high-level mathematical abilities. The research method used was a systematic literature review (SLR).

SLR is a research method that aims to comprehensively find and synthesize research that refers to specific questions, using organized, transparent, and replicable procedures at every step in the process [6]. A good SLR takes sufficient precautions to minimize errors and bias. This is very important in research synthesis, because bias can appear in the original study as well as in the publication, dissemination, and review process, and these biases can be cumulative. Bias consistently exaggerate or underestimate effects, and that can lead to false conclusions. Like any good study, a systematic review follows a protocol (a detailed plan) that first sets out its main objectives, concepts, and methods. The steps and decisions are carefully documented so that the reader can follow and evaluate the reviewers" method.

In this study, the main objective is to describe the results of PBL implementation on high-level mathematical abilities, including understanding, problem-solving, creative thinking, and mathematical literacy, reviewed based on the study year, study level, study duration, and sample size. Therefore, the essential stage of SLR is data collection in the form of experimental research results on PBL to improve these mathematical abilities. Through the extracted PBL research data, the researcher asks some relevant questions as follows.

1. How is the description of the effect of PBL on improving mathematical competence based on the year of study?
2. How is the description of the effect of PBL on improving mathematical competence based on study levels?
3. How is the description of the effect of PBL on improving mathematical competence based on the duration of experiment?
4. How is the description of the effect of PBL on improving mathematical competence based on sample size?

2. Method

2.1 Systematic Literature Review

The method used in this research is a systematic literature review (SLR), which is a survey-based quantitative descriptive approach [22]. The survey was conducted on secondary data, namely in the form of primary research results regarding the effect of the PBL model on the comprehension, problem-solving, critical thinking and mathematical literacy abilities of elementary, junior high and high school students.

The research stages include data collection, data analysis, and conclusions. The data collected are in the form of primary studies that have been made into national journal articles, data are collected from electronic databases that are registered and indexed by Google Scholar, Semantic Scholar, Garuda Portal, DOAJ, ERIC, and direct url of national journals. Furthermore, the extraction of all articles found was carried out. Only articles that are relevant and meet the inclusion criteria are included in the analysis stage.

2.2 Inclusion Criteria

To obtain data that is in accordance with the objectives of the study, the following inclusion criteria were determined:

1. The article is the result of mathematics education research
2. Articles published in the period 2010-2020
3. Research in the form of experiments by applying PBL to improve mathematical competence
4. Studies without a control group were not included in the analysis.

2.3. Research Instruments

The research instrument was in the form of an observation sheet or protocol relating to inclusion and exclusion criteria with criteria based on the study year, duration of the experiment, study level, and sample size.

2.4. Population and Sample

The population in this study is all experimental research on the effect of PBL for increasing mathematical competence which includes mathematical understanding, problem solving, creative thinking, or mathematical literacy that has been published in various publishers. Based on a search using a search engine, a sample of 117 experimental studies that are relevant and worthy of systematic review was obtained.

3. Result and Discussion

3.1. Studies based on criteria

By applying the inclusion criteria to all relevant studies, they were further categorized based on four moderating variables, namely study year, study level, duration of experiment, and sample size. The descriptive data is presented in Table 1.

Table 1. Number of studies based on criteria

No	Criteria	Mathematical Competence			
		Understanding	Problem-solving	Creative thinking	Litireacy
Year of Study	2010-2012	3	2	2	2
	2013-2015	9	4	5	4
	2016-2018	11	11	4	7
	2019-2020	15	27	6	3
Study level	SD	5	6	3	
	SMP	24	31	8	4
	SMA	9	9	6	12
Duraton of eksperiment	3-4	7	9	3	4
	>4	31	37	14	12

Sample size	<30	22	26	5	6
	>=30	16	20	12	10
Total		38	46	17	16

Based on Table 1, in a period of 10 years, it has been dominated by research on improving problem solving skills, and has been successfully published in various indexed journals. This indicates that the mathematics learning orientation set out in the 2013 curriculum and promoted by NCTM has at least been responded to by many researchers. Likewise, research to improve mathematical understanding can be said to be quite a lot, while research related to creative thinking and literacy is still lacking. This is a challenge for researchers, to keep trying to develop mathematical literacy skills through PBL. To obtain information more explicitly, it will then be discussed according to the moderator variables that have been set.

3.2. Year of study

The grouping based on the study time is only divided into four periods, namely from 2010-2012-2013-2015-2016-2018-2020. In that period, the following data were obtained.

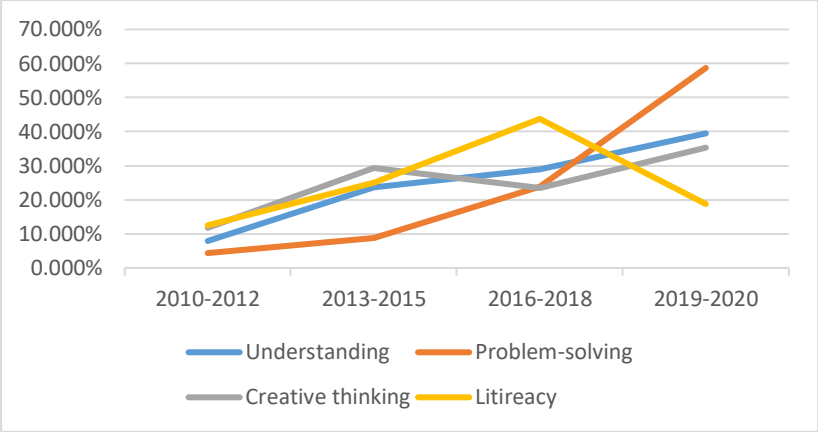


Figure 1. Data based on year of study

From Figure 1, it can be concluded that PBL research to improve mathematical competence tends to increase from each period, especially after 2016-2020, and problem-solving ability is the most researched competency compared to the other three competencies. This suggests that researchers have better interest in problem-solving skills, while interest in researching literacy and critical thinking is less clear. Perhaps these two competencies are more widely researched through the application of other methods. These results indicate that PBL does have good potential to improve mathematical competence, as has been widely discussed [23, 24].

3.3. Study level

Grouping based on the study level is divided into three categories, namely Elementary school, junior high school, and senior high school. The number of experimental studies based on the study level is presented in Figure 2.

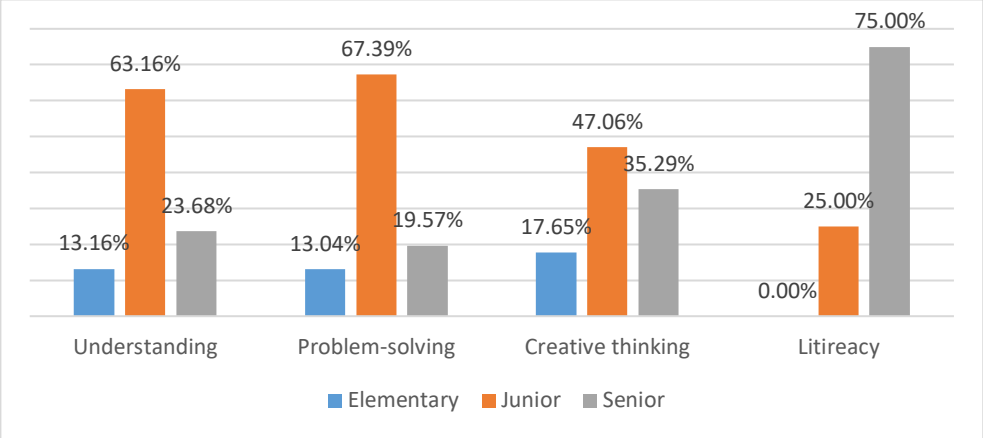


Figure 2. Data based on the study level

From the Figure 2, it can be interpreted that all mathematical abilities, especially mathematical solving abilities, are studied more at the junior high school level, except that mathematical literacy is mostly studied in high school, while in elementary school there is no published literacy research. This is somewhat of a concern because literacy is a very important competency to be developed from an early age.

3.4. Duration of experiment

The grouping based on the duration of experiment was divided into two groups, namely the PBL study which was conducted for less than 4 meetings, and which was conducted as many as 4 or more meetings. The study percentage is presented in Figure 3.

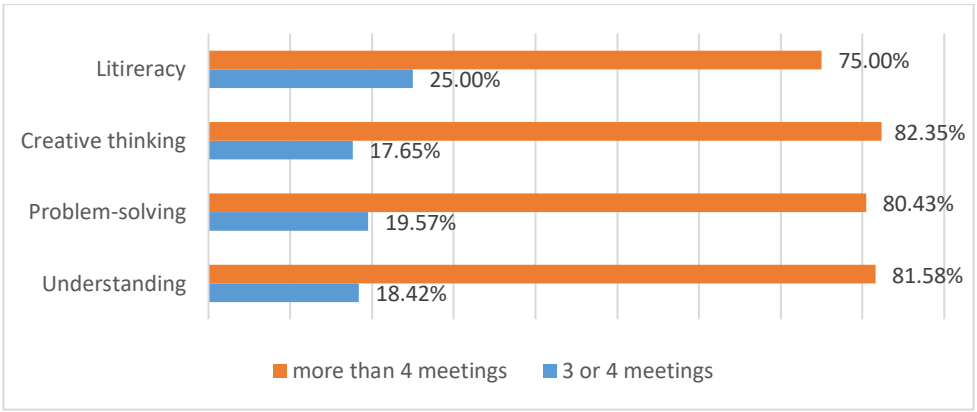


Figure 3. Data based on the duration of experiment

From the Figure 3, it can be seen that all studies were conducted in four or more meetings. For studies that were conducted, less than four meetings were dominated by PBL research to increase literacy. Compared to those with more than four meetings, it was dominated by research on the effect of PBL on increasing critical thinking.

3.5. Sample size

The study based on the sample size was grouped into two groups, namely samples with a size of less than 30 and samples with 30 or more. The data is presented in Figure 4.

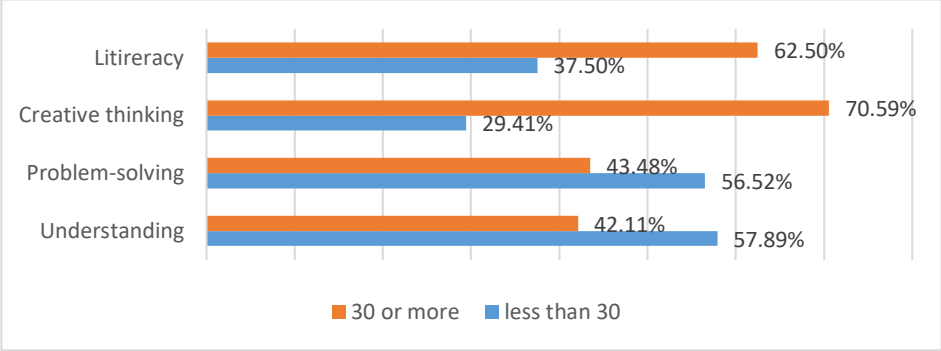


Figure 4. Data based on sample size

Based on the Figure 4, it can be interpreted that PBL research to improve understanding and solving mathematical problems in the 2010-2020 period was dominated by research with a small sample or less than 30, while critical thinking and literacy skills were dominated by research with a large sample or a size of 30. or more. This implies that the researcher.

4. Conclusion

The research on the effect of PBL on improving mathematical abilities has received good attention, especially in increasing understanding and solving mathematical problems, while for creative thinking skills and mathematical literacy are still less published. This systematic review recommends being followed up with a stronger method, namely meta-analysis, by considering several moderating variables. The question for a fairly important meta-analysis is whether PBL has a significant effect on improving math skills.

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