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# The Impact of Problem-Based Learning on Learning Outcomes Using the Effect Size Calculator for T-Test

**Muslim[1*], Ambiyar[2], Wakhinuddin[3], Usmeldi[4], Ahmad Arif[5]**
[1,2,3,4,5] Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia
*Corresponding author: muslim@ft.unp.ac.id

## *Abstrak*

*Berbagai macam penelitian yang telah dilakukan mengenai pengaruh pembelajaran berbasis masalah terhadap hasil belajar mempunyai keluaran yang bervariasi dan terkadang bertentangan, sehingga perlu dilakukan meta-analisis. Artikel ini menyajikan meta-analisis mengenai dampak pembelajaran berbasis masalah dalam meningkatkan hasil belajar siswa. Jenis penelitian ini berdasarkan sumber meta analisis berupa penelitian eksperimental atau quasi eksperimen dan observasional dengan pendekatan kuantitatif. Analisis data dilihat dari effect size menggunakan kalkulator untuk uji t. Subyek dalam penelitian adalah penelitian-penelitian yang dikumpulkan dalam bentuk artikel-artikel yang berkaitan dengan tujuan penelitian. Hasil analisis terhadap 26 sumber artikel, diperoleh rata-rata effect size sekitar 0,79 dengan kategori sedang. Pembelajaran berbasis masalah memang efektif dalam meningkatkan hasil belajar siswa. Implikasi dari melakukan meta-analisis adalah untuk dapat mengetahui lebih akurat tentang pendekatan pembelajaran berbasis masalah yang efektif dalam meningkatkan hasil belajar siswa serta informasi yang berguna bagi pengambil kebijakan di bidang pendidikan.*

***Kata kunci:*** *Calculator for t-test, meta-analisis, effect size, pembelajaran berbasis masalah*

## Abstract

Various kinds of research that has been conducted on the effect of problem-based learning on learning outcomes have varied and sometimes conflicting outputs, so it is necessary to carry out a meta-analysis. This article presents a meta-analysis regarding the impact of problem-based learning in improving student learning outcomes. This type of research is based on the source of meta-analysis in the form of experimental or quasi-experimental and observational research with a quantitative approach. Data analysis was seen from the effect size using a calculator for t-test. The subjects in the research are studies that are collected in the form of articles related to the purpose of the research. The results of the analysis of 26 article sources, obtained an average effect size of around 0.79 in the medium category. Problem-based learning is indeed effective in improving student learning outcomes. The implication of doing meta-analysis is to be able to find out more accurately about problem-based learning approaches that are effective in improving student learning outcomes as well as useful information for policy makers in the field of education.

**Keywords:** Calculator for t-test, Meta-analysis, Effect size, Problem-based learning.

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## 1. INTRODUCTION

The challenge for education is to ensure the development of student's grades, both in terms of achieving knowledge and skills, must be maximized. Low learning outcomes due to the large number of conventional strategies used in imparting knowledge to students need to be overcome (Gorghiu et al., 2015; Muslim et al., 2019; Parwez, 2017). This is a challenge for educators in imparting knowledge and skills to their students. Challenges like this must be overcome by utilizing technology, evaluation, and strategies or methods used in learning activities (Bains et al., 2022; Mardhiyah et al., 2021; Nirmayani & Dewi, 2021). In the current era of globalization, problem-based learning is a learning method that can be a mainstay, especially in educational institutions in improving student learning outcomes (Kang & Kim, 2021; Rahayu et al., 2022; Saqr et al., 2018). Problem-based learning is one method that makes students more active in the learning process. Problem-based learning is learning that focuses on problems given to students (Kwon et al., 2021; Oganisjana & Laizans, 2015; Zotou et al., 2020). Students are required to be able to overcome these problems following the conditions that exist in the real world. Problem-based learning uses

problems as the first step in gathering and integrating knowledge based on experiences found by students during actual activities (Louw & Deacon, 2020; Muslim et al., 2020). This learning activity is designed to solve complex problems given to students and it is hoped that students can understand them. The application of this learning will help students hone and improve critical thinking skills in solving complex problems by utilizing students' communication, collaboration, and creativity skills (Andersen et al., 2019; Hung, 2011; Zamir et al., 2022). This approach to learning will involve students in more specific discussion activities by providing examples of real-world cases. Problem-based learning is the center of learning in the students themselves or commonly known as Student Center Learning (CTL) (C. L. Lin, 2018; Muslim et al., 2021).

Theoretically, problem-based learning will allow students to achieve cognitive aspects of higher-order thinking skills and motivate students to focus on learning. On average, research that applies this learning will get significant results, whereas problem-based learning will optimally improve the quality of learning outcomes. Using this approach will make students feel more positive about learning (Rosyida et al., 2019; Winarti et al., 2020). On the other hand, it was found that this learning had several weaknesses including students feeling disinterested if the problems given were difficult to solve and students feeling reluctant to try them (Dewi, 2022; Kärchner et al., 2022). Another weakness is that it takes quite a long time, so it is feared that you will not be able to complete the assigned task on time. Many research studies have been conducted in measuring the effect of problem-based learning on student learning outcomes. However, several research studies show different results from one another. Conditions like this are caused by various factors such as variations used in the learning process. The existence of variations in the use of designs in research will affect the results. Apart from the variety of research designs used, other factors that make the final study results different are the use of research samples, instruments in measurement, the variables used and the lack of explanation regarding the use of technology in the application of problem-based learning. The next factor is the quality of the problems given and the involvement of students in the learning process.

Gap analysis becomes more important in identifying the factors that influence the effectiveness of this learning. It is necessary to develop strategies to improve the effectiveness of problem-based learning in improving student learning outcomes. If the problem given is too easy during the learning process, there will be no feeling of being challenged or actively involved in finding solutions to these problems (Sinprakob & Songkram, 2015; Wang et al., 2016). The problems given should require students' critical thinking and higher problem-solving skills. Students will be more deeply involved in thought processes and should improve in-depth skills in solving problems (Aprelia et al., 2019; Gao et al., 2020). Although many studies regarding problem-based learning are effective in improving student learning outcomes, there are many discrepancies regarding the impact of this learning-on-learning outcomes.

For this to be resolved, a meta-analytic study is needed in uniting the results of previous research from various fields of study, especially in the world of education. This will provide some more accurate descriptions in solving problems regarding the impact of problem-based learning in improving student learning outcomes. Several meta-analysis activities that have been carried out show that problem-based learning can improve learning outcomes significantly compared to conventional learning. A meta-analysis conducted by previous study found that problem-based learning had a positive impact on student learning outcomes in the fields of mathematics and social studies (Yunita et al., 2020). Another meta-analysis conducted by other study shows that problem-based learning can improve problem-solving skills and conceptual abilities that are learned in a more real context (Demirel & Dağyar, 2016). The meta-analysis study conducted in this study focused on education in

general and vocational education at the level of elementary school education to higher education regarding problem-based learning in improving student learning outcomes. Based on this, the purpose of this study is conducted meta-analysis of the impact of problem-based learning in improving student learning outcomes. Meta-analysis study activities by collecting various data from various research studies that are relevant to the topic then carried out statistical analysis of the data that has been taken. This is done in order to be able to provide information that is very useful for teachers as educators and policy makers in the world of education as well as for subsequent research regarding the development of effective learning methods in improving student learning outcomes.

## 2. METHODS

Meta-analysis activity is an analytical activity that aims to combine the results of research that has been done before on a particular topic. The type of research used is based on analysis of sources carried out by meta-analysis in the form of experimental or quasi-experimental and observational research using a quantitative approach (Cooper et al., 2019). The stages used in this meta-analysis study are: 1) preparation and identification; 2) implementation and screening; 3) final collection of reference sources. The first stage is preparation by finding sources of articles to be analyzed taken from Google Scholar in national journals accredited (Liu, Y., & Pasztor, 2022). The following is the flow of research data collection based on the provisions of meta-analysis, which can be seen in Figure 1.

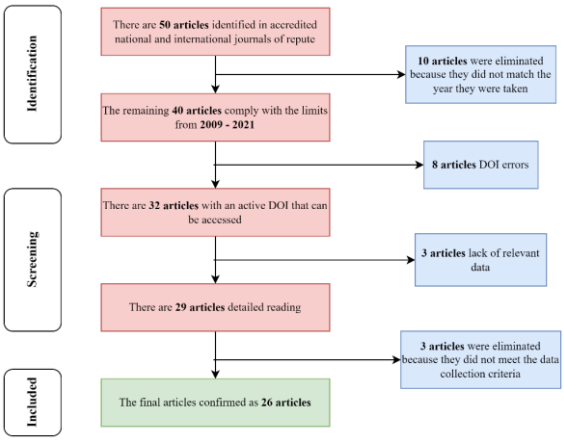


**Figure 1**. Prisma Analysis of Adaptation Studies

So that the quality of the research and the transparency that was carried out complied with the criteria for writing a meta-analysis, data collection activities used PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) (Page et al., 2021). The inclusion criteria aim to exclude studies that do not meet the requirements so that they are not included in the meta-analysis. This is determined to ensure that the data analysis found is of good quality and relevant to the research objectives. The grids that can be described in these criteria can be in the form of research activities by reporting problem-based learning outcomes on learning outcomes, using experimental or quasi-experimental and observational designs, using interventions that are relevant to the research objectives and meeting the research quality criteria that have been set by meta- analysis. If these inclusion criteria are met, the data found is more valid and can provide more reliable results and has good meaning. Data analysis in comparing learning groups is seen from the effect size (ES) using a calculator for a t-test (Stangroom, 2022). The calculations in this ES analysis use the average in a group by considering the pretest-post-test value and the group average value by

paying attention to the average value obtained in the experimental and control classes. The formula used for the pretest-post-test uses the Formula-1 (Fr-1) code. While the group average uses the Formula-2 (Fr-2) code (Becker & Park, 2011). The data obtained will be processed using the ES calculator for the t-test which is used to look for ES at each level of data found. After obtaining the ES in each article that has been analyzed, it will be interpreted in the data interpretation table to look for ES categories at the Low (Lo), Medium (Md), and High (Hi) levels. Once obtained, then conclusions are drawn from the data that has been found. The result of this meta-analysis activity is to evaluate the effectiveness of problem-based learning in improving student learning outcomes.

## 3. RESULTS AND DISCUSSION

### Results

Meta-analysis of the effect of problem-based learning on students' cognitive learning outcomes is a basic part of this research activity. Based on the presentation that has been explained in the research method, it was found that 26 articles had been analyzed and then the effect size value was obtained with the help of a calculator for the t-test. This research was conducted based on several levels of education starting from elementary school (SD) equivalent, junior high school (SMP) equivalent, senior high school (SMA) equivalent, and finally tertiary education (PT). The articles to be analyzed range from 2009 to 2021 to look for an analysis of the ES value based on the distribution of the articles obtained. The recapitulation of articles and educational levels and ES values can be seen in Table 1.

**Table 1.** Recapitulation of Articles as a Source of Meta-Analysis

| No. | Source Meta-analysis | Learning outcomes | Effect Size Data | | | | |
|---|---|---|---|---|---|---|---|
| | | | N total | ES | Level | Category | Information |
| 1 | (Taqiyyah et al., 2017) | S | 60 | 1.14 | SMP | Hi | Fr-2 |
| 2 | (Yarid & Ariswan, 2016) | S | 60 | 0.38 | SMA | Md | Fr-2 |
| 3 | (Damarwan et al., 2018) | E-S | 60 | 1.36 | SMK | Hi | Fr-1 |
| 4 | (Fatimah, 2012) | S | 77 | 0.02 | PT | Lo | Fr-1 |
| 5 | (Widiana et al., 2020) | S | 73 | 2.23 | SD | Hi | Fr-2 |
| 6 | (Chung et al., 2016) | V-T-E | 102 | 0.79 | PT | Md | Fr-1 |
| 7 | (Astutik, 2017) | S | 58 | 4.22 | SMP | Hi | Fr-1 |
| 8 | (Zuraida & Karyati, 2018) | S | 60 | 0.01 | SMP | Lo | Fr-1 |
| 9 | (Kurniyawati et al., 2019) | S-M | 32 | 0.21 | SMP | Md | Fr-2 |
| 10 | (Severiens & Schmidt, 2009) | S | 215 | 1.11 | PT | Hi | Fr-2 |
| 11 | (Anesa & Ahda, 2021) | S | 54 | 1.36 | PT | Hi | Fr-2 |
| 12 | (Celik et al., 2011) | S-M | 44 | 0.99 | PT | Hi | Fr-2 |
| 13 | (Gurses et al., 2015) | S | 62 | 0.56 | PT | Md | Fr-1 |
| 14 | (Tarmizi & Bayat, 2012) | S-M | 64 | 0.03 | PT | Lo | Fr-2 |
| 15 | (Kazemi & Ghoraishi, 2012) | S-M | 83 | 0.26 | PT | Md | Fr-2 |

| No. | Source Meta-analysis | Learning outcomes | Effect Size Data | | | | |
|---|---|---|---|---|---|---|---|
| | | | N total | ES | Level | Category | Information |
| 16 | (Bahri et al., 2012) | V-T-E | 40 | 1.88 | PT | Hi | Fr-2 |
| 17 | (Benli & Sarikaya, 2012) | S | 64 | 0.24 | PT | Md | Fr-1 |
| 18 | (Ersoy & Başer, 2014) | S | 83 | 1.33 | PT | Hi | Fr-1 |
| 19 | (Tarmizi et al., 2010) | S-M | 53 | 0.38 | SMA | Md | Fr-2 |
| 20 | (Turan et al., 2009) | S | 599 | 0.17 | PT | Lo | Fr-2 |
| 21 | (Tarmizi & Bayat, 2010) | S-M | 31 | 0.06 | PT | Lo | Fr-2 |
| 22 | (Alias et al., 2015) | V-T-E | 82 | 0.01 | PT | Lo | Fr-2 |
| 23 | (Abdullah et al., 2010) | S-M | 53 | 0.33 | SMP | Md | Fr-2 |
| 24 | (Selçuk & Çalışkan, 2010) | S-M | 25 | 0.51 | PT | Md | Fr-1 |
| 25 | (Bayat & Tarmizi, 2012) | S | 48 | 0.43 | PT | Md | Fr-2 |
| 26 | (Koray & Koray, 2013) | S | 52 | 0.46 | SMP | Md | Fr-1 |
| | $Average\ ES = \frac{\sum ES}{n} = \frac{20.47}{26}$ | | | | | | |
| | $\boldsymbol{Average\ ES = 0.79}$ **Medium Category** | | | | | | |

Information:

Fr-1 : Formula 1
Fr-2 : Formula 2
Hi : High
Md : Medium
Lo : Low

S : Science
E-S : Engineering Science
S-M : Science Mathematic
V-T-E : Vocational Technology Education

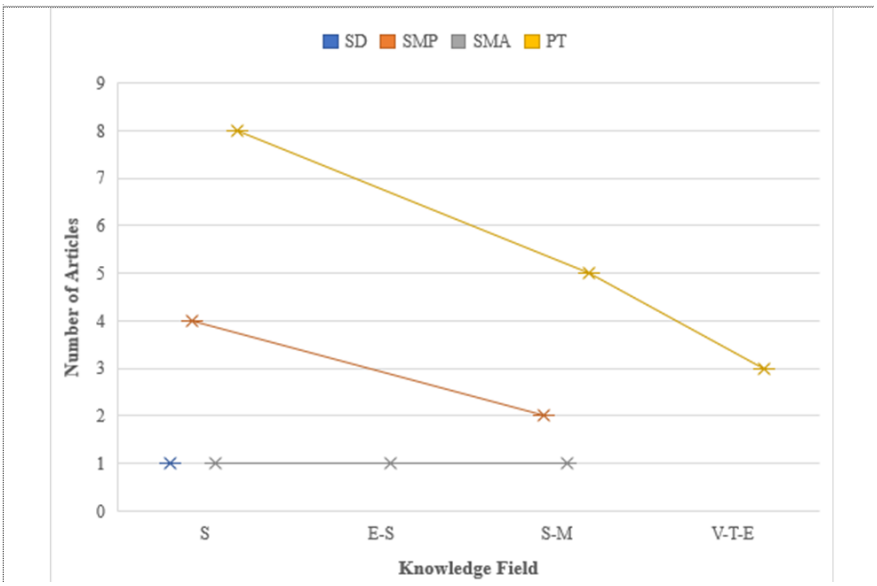


**Figure 2.** Educational Level Based on Four Expertise Fields

Learning outcomes are integrated in the fields of science, engineering science, mathematic science and vocational technology education based on the data collection that has been done, these areas of expertise are spread across various levels of education starting from elementary school, junior high school, high school, and college. The following describes the learning outcomes in each area of expertise based on the level of education can be seen in Figure 2.

Figure 2 is the division of areas of expertise based on each level of education. At the elementary school level, the area of expertise used is based on the results of an analysis of the source of the articles used, there is one article with the area of expertise in science. At the junior high school education level, there are 4 areas of expertise in the science category and 2 areas of expertise in the mathematic science category. Senior high school level equivalent, 1 article is in the science field, 1 article is in the engineering science area of expertise and 1 article is in the mathematic science area of expertise. Finally, at the university level, articles with the most fields of study are at this level, where in the field of science there are 8 articles, 5 articles in the field of mathematic science and 3 articles in the field of vocational technology education. Furthermore, the data will be sorted based on the percentage of articles that have been analyzed based on the level of each education. The data can be seen in Figure 3.

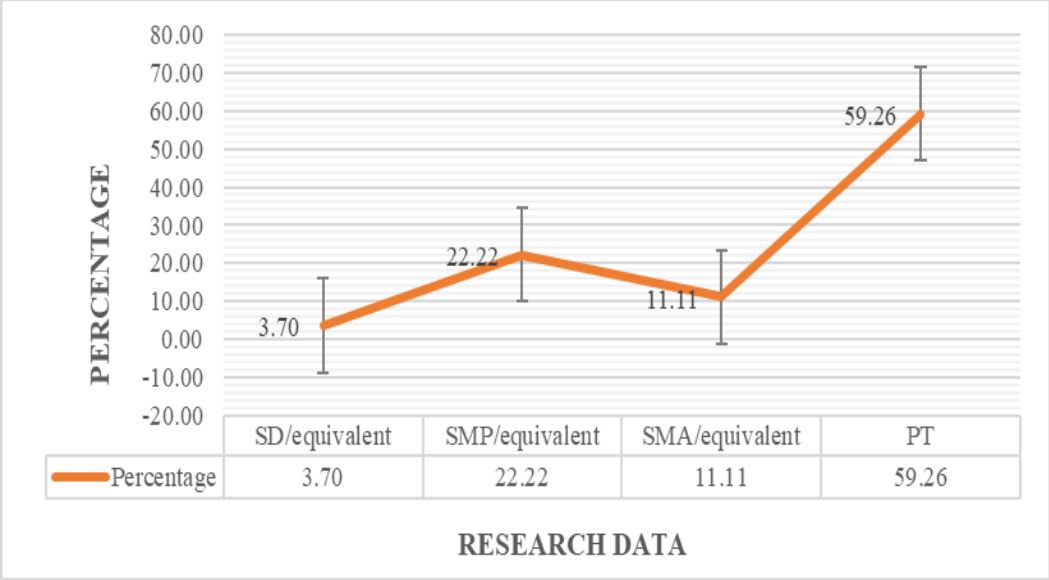


**Figure 3.** Percentage of Research Data by Education Level

**Figure 3** is the distribution of data based on educational level from the 26 articles analyzed. The most analyzed articles were at the tertiary level with a percentage of 59.26% while the lowest were at the elementary school level with a percentage of 3.70%. The number of articles at the junior high school level is in the middle position with a percentage of 22.22%. A total of 26 articles analyzed based on the year of publication can be seen from the highest year which is the most recent article analyzed. The number of studies from the reference limits previously described shows the number of each article found each year. There is not much improvement in this research, this is due to the limited scope of taking articles, for example restrictions at the level of national journals which are only taken at the level of sinta 1 and sinta 2. The following can be explained in **Figure 4** regarding the number of articles analyzed based on the year of publication.

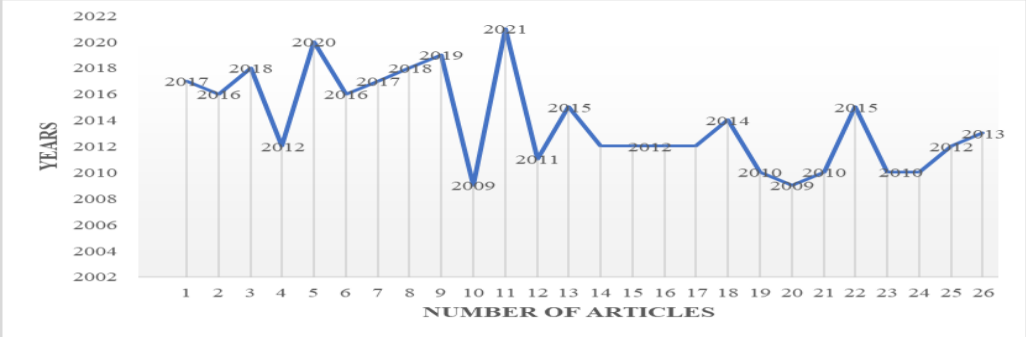


**Figure 4.** Number of Articles by Year of Publication

Figure 4 shows the number of articles analyzed based on the level of publication year taken. The articles used started from 2009 to 2021. The most used articles were in 2012 with a total of 6 source articles. In 2010 there were 4 articles, while other years in the range from 2009 to 2021 were filled with 1 and 2 articles so a total of 26 articles. Then the distribution of articles varies in number based on the level of the year that has been analyzed to get ES values in each of the High (Hi), Medium (Md), and Low (Lo) categories. High, medium, and low data in the category of ES scores at each level of education can be seen in Figure 5.

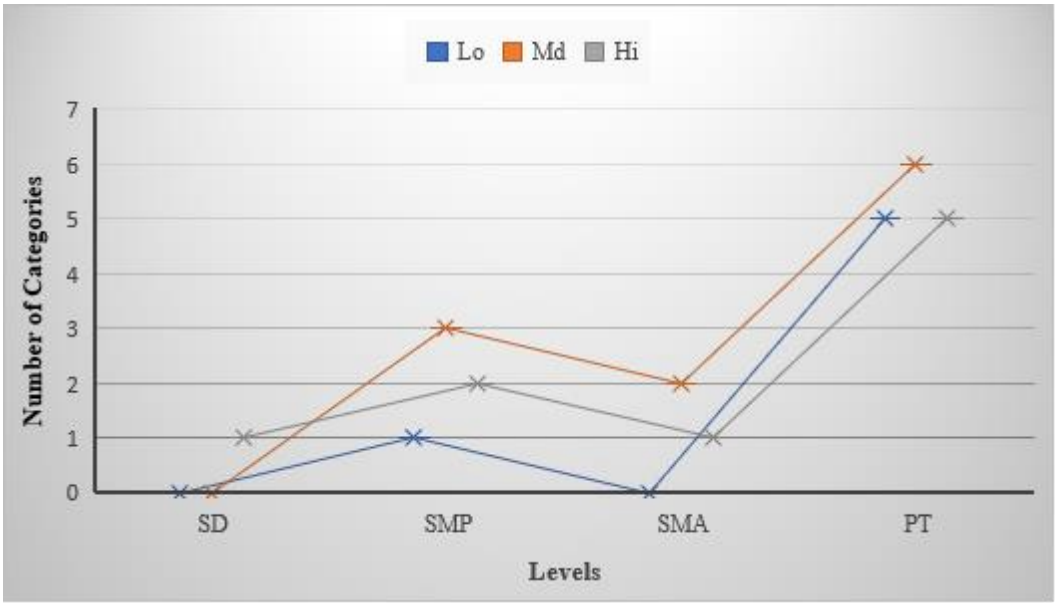


**Figure 5.** Number of Education Levels by Category Effect Size

Figure 5 describes the ES result categories at each level/level of education that have been analyzed using the ES calculator for t-test. Most ES scores were analyzed at the tertiary level, namely 5 articles in the high category, 6 articles in the medium category and 5 articles in the low category. The data is obtained from the analysis of articles that have been found and is indeed the most widely applied at the tertiary level. The total for each level of education in the high category is 9 articles, in the medium category is 11 articles and in the low category is 6 articles. Because most of the research subjects came from the tertiary level, the results that obtained the most ES scores were at that level. The results of the ES scores for the entire article can be seen in Figure 6.

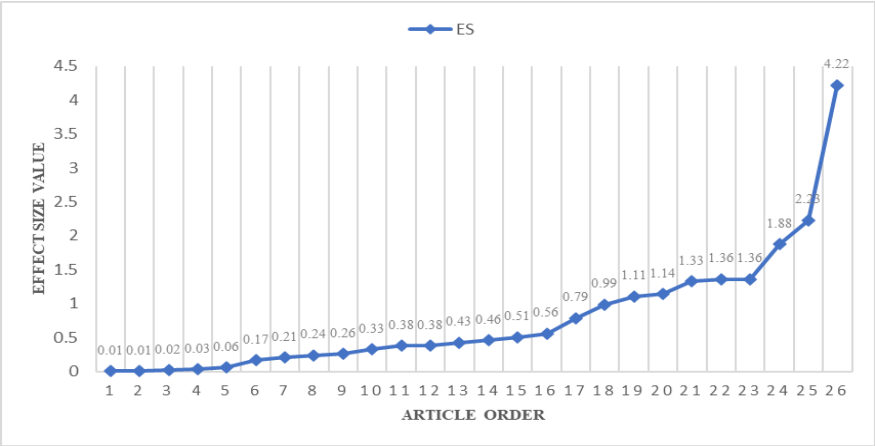


**Figure 6.** Effect Size Value Results for Each Article

Figure 6 shows the ES value for each article. The lowest ES value is 0.01 and the highest is 4.22. This means that the higher ES value of the calculator for the t-test seen from the average pretest-posttest value and the average value of the experimental-control class. The average ES value is around 0.79 in the moderate category. It can be concluded that the problem-based learning approach has a considerable influence compared to the control class.

## Discussion

Based on 26 types of research that have been meta-analyzed, 19 studies are showing problem-based learning has a positive and significant impact on improving learning outcomes, while 7 other studies have had a positive impact, but the increase in learning outcomes is still in the low category. This happens due to many factors, one of which is the research design used or the method applied in carrying out the research activities (Hung et al., 2007; Samani et al., 2019; Tista, 2017). Problem-based learning will provide opportunities for students to think higher in solving the tasks or problems given. Students no longer rely on memory in learning, and having responsibility for solving problems will form a critical thinking process because the focus of this learning is on the students themselves. In line with previous study thinking critically will make students skilled in solving a given problem (Sriamah et al., 2020). Students can provide many possibilities for finding solutions based on the ideas that arise during the process of completing a given task. According to other study, the better the student learning outcomes, it can be interpreted that these students study. The more you learn, the better the problem-solving will be (Ari & Katrancı, 2014).

Problem-based learning certainly involves students finding solutions to problems that have been given independently or in collaboration with colleagues in solving these problems. This certainly provides a more interactive, innovative, and certainly collaborative learning experience (Balan et al., 2019; Chang et al., 2020). In line with research by taking a problem-based approach, students will be more active in learning, able to solve problems on their own, and can also exchange ideas with classmates to find solutions to problems given by the teacher (Zhang & Hwang, 2023). Learning activities are carried out conventionally, the condition is that students only get information from the teacher or textbooks and most students are required to remember information in the form of answers given by the teacher (L.-F. Lin, 2018; Luke et al., 2021). Using problem-based learning, students are invited to be more active in solving problems independently and finding solutions to problems, so the focus of learning has been shifted to students and not focused on what teachers provide in conventional learning (Moutinho et al., 2015; Peffer et al., 2021). This learning can also help students develop their social skills by collaborating with classmates. Students must carry out

cooperative activities in solving problems. This certainly helps social skills, especially in facing the world of work in the future. Opinions state that problem-based learning will provide a more interactive, innovative learning experience and encourage students to be creative in solving problems (Kwon et al., 2021). Students learning abilities will increase because the application of problem-based learning has work steps that are quite easy to do. Students tend to be more active in learning so it is easy to find the concepts being studied (Acharya & Sinha, 2017; Günter, 2020; Nurtanto et al., 2018). That is because students can solve their problems, and can understand, and easily remember the series of problem-solving.

The use of technology in problem-based learning activities can be a learning facility by providing access to information so that it can help students solve problems. One of the technologies used in this learning is information technology which can provide students access to information on relevant topics. In line with the statement, information technology can be used to improve student communication and collaboration in the learning process (Ioannou et al., 2016; Ran et al., 2021; Yağcı, 2018). According to previous study shows that the use of technology in learning will improve students' cooperative skills and problem solving (Boye & Agyei, 2023). Because technology can help students to get a better learning experience. However, the use of information technology must be managed appropriately so that it is effective and does not interfere with the process of learning activities and student involvement in learning. Research from other study reports that problem-based learning will improve student learning outcomes (Li et al., 2020). This learning has a big influence because it uses a method that makes students more active in learning. This learning is believed to be able to improve student learning in class. In line with the statement, the success of this learning is supported by the success of its application in the learning process (Phungsuk et al., 2017). Because basically problem-based learning requires students to be able to play an even more active role in learning, be able to make decisions, analyze problem-solving solutions and be able to collect data so that they can be presented. Student communication will increase in a better direction and it will be easy to socialize with various things. This is in line with research, where in addition to increasing student academic achievement, understanding of communication also increases in problem-based learning (Gurses et al., 2015; Yuan et al., 2020). Students will feel motivated in solving the problems given and are triggered to express solutions to these problems.

The ability of students also depends on their success in solving problems. According to previous study students who have better initial abilities will find it easier to solve the problems given (Raharjo et al., 2018). Solutions to problems are obtained based on experiences obtained independently in learning. Achievements like this are the ability to think critically, and to be able to carry out systematic analysis activities in determining alternative answers. On the other hand there is researcher state there is a relationship between educators' understanding of using and applying problem-based learning with student learning outcomes (Panlumlers & Wannapiroon, 2015). Referring to the results of the meta-analysis, problem-based learning can form students who have high reasoning, can think critically, and can solve problems. Based on the results of the discussions that have been described, problem-based learning can help students think critically, make students skilled in solving problems, and be active in learning. On the other hand, students can also develop their social skills by collaborating with classmates in solving problems. In line with the opinion state that project-based learning will develop student skills both from an independent and social perspective in the application process (Santos et al., 2023). This learning can also encourage students to be more creative and independent in solving problems so that it will be easier for students to understand and remember the concepts they have learned (Goyal et al., 2022; Zen et al., 2022). This study has several limitations, namely the data sources analyzed came from experimental or quasi-experimental and observational research. This will limit the

generalization of learning outcomes to real-world applications. Another limitation is that this study does not evaluate other factors that might affect student learning outcomes such as environmental factors, motivation, and so on. More recent research is needed to cover the deficiencies of the limitations that have been presented as well as more comprehensive research activities in evaluating the effectiveness of problem-based learning in improving student learning outcomes.

## 4. CONCLUSION

Problem-based learning has a role in increasing cognitive abilities, critical thinking, creativity, and students' ability to solve problems. Students' social skills will develop because of collaboration in the learning process. On the other hand, students will be encouraged to be more creative and independent in learning, especially in problem-solving activities. This learning has a very large effect on improving the learning outcomes of students who have lower abilities compared to students who already have high learning abilities. This shows that problem-based learning can be an effective choice in helping students with learning difficulties. An important implication of doing a meta-analysis is to be able to find out more accurately about problem-based learning approaches that are effective in improving student learning outcomes as well as useful information for policymakers in the field of education and practitioners in developing this learning model.

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