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The effect of teaching props on the mathematical problem-solving skills: A meta-analysis study

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Abstract

Researchers have widely researched the effects of teaching props, and most concluded that, statistically, there is an effect on problem-solving ability. However, how significant is the effect on problem-solving ability, and whether their research results are parallel to other research they have yet to do? So, the reliability of research related to teaching props still needs to be considered. This research aims to analyze the results that examine teaching props on problem-solving abilities. The method used in this research is meta-analysis. This research was carried out through meta-analysis stages, namely determining inclusion criteria, collecting data and coding variables, statistical analysis by determining the effect size, and making conclusions from the data obtained. Data collection was carried out by collecting data from research conducted from 2018 to 2023 on the Google Scholar database. This data collection obtained twenty-six (26) studies that met the inclusion criteria for extraction from research and development, experimental, and quasi-experimental. Effect size measures the effect of teaching props on students' problem-solving abilities. Based on these calculations, an effect size value of 2.449. This research indicates a significant and positive influence between teaching props and students' problem-solving skills, especially in mathematical learning. Therefore, it is necessary to develop teaching props to improve mathematical problem-solving skills.

Keywords:
Effect, Learning props, Meta-analysis, Problem-solving skills

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1. INTRODUCTION

Problem-solving skills are a learning process that awakens students to play an active role in receiving and responding to questions submitted well and overcoming difficulties in solving a problem (Harisman et al., 2020; Rasmitadila et al., 2021; Steyn & Adendorff, 2020). Problem-solving skills are also one of the abilities students must have after studying mathematics (Özreçberoğlu & Çağanağa, 2018; Wijayanti et al., 2022). Problem-solving is seen as applying concepts and skills, whereas problem-solving usually involves some combination of ideas and skills in a new situation (van Merriënboer, 2013). Even the National Council of Teachers of Mathematics also made problem-solving one of the focuses of mathematics learning objectives in schools, in addition to critical thinking skills (National Council of Teachers of Mathematics, 2020; Olivares et al., 2021; Piñeiro et al., 2022). Likewise, in Indonesia, the ability to solve mathematical problems is still one of the goals of learning mathematics (Hendriana et al., 2018; Maulidia et al., 2019; Pusporini et al., 2023). Because these two abilities are used to understand and critique their world, preparing them to be contributing leaders in society (National Council of Teachers of Mathematics, 2020). This shows that problem-solving skills are still a focus, and conducting research in mathematics education nationally (Indonesia) and globally is essential.

Mathematical problem-solving skills are skills that all individuals need in decision-making, the workforce, their communities, and daily life (Huinker et al., 2020). With problem-solving skills, a person can understand and interpret numerical information (i.e. statistics), make more rational decisions because they use logic and reasoning, and plan and predict based on existing data (Hutajulu et al., 2022; Kurniansyah et al., 2022; Murtafiah et al., 2023). Problem-solving skills are generally considered the most significant cognitive activity in daily life. A study states that most people are needed and appreciated for the problem-solving process they produce (van Aken & Berends, 2012). Problem-solving skill is an ability that can resolve a situation in which he is aware there is a problem in the situation, knowing that there is a problem that needs to be done, feels like doing it and getting it done, but doesn't can solve it straight away (Murtafiah et al., 2023; Setiawan, 2022).

Students solve mathematical problems using three interrelated abilities. The three abilities are understanding the problem, designing a mathematical model, solving the model or interpreting the solution obtained (Ambarita et al., 2018; Zulkarnaen & Kusumah, 2019). The ability to understand a problem is finding the exact problem being faced (Sternad, 2021). Understanding a problem is identifying what is known and what is asked of a mathematical problem (Meutia et al., 2020; Murtafiah et al., 2024). The ability to design mathematical models is the ability to plan mathematical equations or functions for a problem students face (Leung & Bolite-Frant, 2015; Siagian et al., 2019). The ability to complete a model or interpret the solution obtained is to complete mathematical modelling designed using known variables from the problem (Schoenfeld, 2014; van Aken & Berends, 2012). The three skills used to solve the problem are broadly in line with four steps of problem-solving from Polya's, namely understanding the problem, which means students identify the information contained in the issues and questions; drawing up a plan, which means students connect previous knowledge with the information contained in the situation and what is asked in the question (Erbilgin & Macur, 2022; Polya, 2014). Questions and carrying out answers, students do calculations and check again, which means they correct the problems they have obtained (Arbo & Ching, 2022; Chidyaka & Nkhata, 2019).

Based on the framework of the Program for International Student Assessment (PISA), solving mathematics has three stages: formulating situations mathematically, using mathematical concepts, facts, and procedures, and interpreting, applying, and evaluating mathematical results (Ambarita et al., 2018; Avvisati & Borgonovi, 2020; Stacey & Turner, 2015). In the first stage, formulating problems mathematically includes identifying opportunities to apply and use mathematics in solving specific problems, providing mathematical structures and representations, identifying variables, and simplifying assumptions in solving problems. In the second stage, using mathematics includes applying mathematical reasoning, concepts, procedures, facts, and tools to obtain mathematical solutions that include calculations, manipulating algebraic forms, equations and mathematical models, analyzing information from diagrams or graphs, developing mathematical explanations, and using mathematical tools to solve problems. In the last stage, interpreting or interpreting mathematics includes reflecting on mathematical solutions and interpreting them according to the context of the problem being solved, including evaluating mathematical solutions and determining or checking the truth and reasons for the results obtained. This is what causes the questions used in PISA to use a problem-solving approach to solve them because these questions cannot be solved typically.

The result of PISA in 2018, released by the Organization for Economic Co-operation and Development (OECD), shows that Indonesia is ranked 74th out of 80 countries (Azizah et al., 2022; Ekowati et al., 2023; Ismawati et al., 2023). Although in 2022, Indonesia's ranking increased, the capability score obtained decreased (Kusmaryono & Kusumaningsih, 2023). These results show that Indonesian students' abilities, especially in the ability to solve mathematical problems, have difficulty obtaining high scores in the PISA mathematics assessment (Afgani & Paradesa, 2021; Kartianom & Ndayizeye, 2017; Kartianom & Retnawati, 2018; Wijaya et al., 2024).

In addition, several research results show that students in Indonesia experience difficulties in dealing with situations that require problem-solving skills using mathematics (Kusumadewi & Retnawati, 2020; Puspitasari et al., 2018; Putri et al., 2022). Students with difficulty solving problems are students with low and high ability (Praekhaow et al., 2021). Students experience problems because they are not used to situations requiring problem-solving skills (Akben, 2020; Yu et al., 2015). Students provide explanations and solutions they understand when solving problems, but when they are not enthusiastic or lack confidence, the problem-solving process stops (Aisyah et al., 2023). The level of students' problem-solving abilities at the stage of understanding the problem is moderate; at the location of planning, the problem is sufficient; at the scene of implementing the plan or calculating, it is high; and at the stage of rechecking the solution, is moderate (Widodo et al., 2019). It can be said that students in Indonesia have yet to be able to solve mathematical problems (Attami et al., 2020; Kamaliyah et al., 2013). Students face various obstacles and challenges when solving problems (Hadi et al., 2018). One factor that influences the test of students' problem-solving abilities is a need for more skills in understanding problems and planning solutions (Hesse et al., 2015; Ibrahim & Widodo, 2020).

Some students' difficulties in solving problems require teachers to design effective and innovative learning processes by fostering student motivation in learning. So, there will be reciprocity between teachers and students to achieve educational goals (Košir & Tement, 2014). One of the innovative ways of learning is by utilizing learning media. Learning media is an educational tool that carries information and stimulates students to increase effectiveness and efficiency in achieving learning goals (Ningrum et al., 2023). One type of learning media in mathematics is mathematics teaching props. Mathematics teaching props are learning media that can help students to concretize abstract concepts (Utami et al., 2022; Verawati et al., 2022). With mathematical teaching props, abstract mathematical concepts can be presented as concrete objects that can be seen, manipulated, and changed (Hakim et al., 2019; Larbi & Mavis, 2016; Mudaly & Naidoo, 2015).

Based on previous research, teaching props can improve students' problem-solving abilities in mathematics (Hakim et al., 2019; Siagian et al., 2019; Ulandari et al., 2019). Other research shows that using teaching props in learning can improve problem-solving thinking skills and increase the completeness of student learning outcomes (Devita et al., 2023; Sugiman et al., 2021). Further research also states that using teaching props can improve students' learning activities, learning motivation, and problem-solving skills (Devita et al., 2023; Lee et al., 2019). In addition, other researchers independently also mentioned the positive impact of using props on other mathematical abilities. For example, visual and concrete props (manipulatives, diagrams, and interactive simulations) can help students understand mathematical concepts (Joan, 2015; Osana & Duponsel, 2016). Research that they have conducted consistently shows that visual and manipulative representations can significantly improve students' understanding of abstract mathematical concepts. In addition, using teaching props supports the development of conceptual knowledge in mathematics and allows students to build a solid foundation for advanced mathematical thinking (Powell, 2021). The research they have conducted consistently shows that visual representations and manipulatives can significantly improve students' understanding of abstract mathematical concepts and encourage deep conceptual understanding and procedural fluency in mathematics.

In addition, teaching props can help improve memory and application. Concrete examples and visual props help students remember mathematical concepts better and apply them to solve real-world problems. Research shows that incorporating real-world examples and hands-on activities into mathematics lessons improves students' ability to recognise and apply mathematical concepts (Tuong et al., 2023; Weinhandl & Lavicza, 2021). Teaching props can help teachers conduct more interactive teaching; their mathematics learning is more exciting and fun for students, and the results lead to increased motivation and participation in class. This study's results align with other studies that use interactive technology and real-world teaching props in mathematics teaching to increase student engagement and interest (Attard & Holmes, 2020; Mulqueeny et al., 2015; Pramuditya et al., 2022). In addition, using teaching props allows teachers to meet various learning styles and abilities by providing a variety of representations and approaches to solving mathematical problems. Using teaching props that accommodate different learning styles can help teachers effectively meet the various needs of students in mathematics classes (Cuevas, 2015).

Concerning this, it can be concluded that previous research results concluded that teaching props used in mathematics learning affect students' mathematical problem-solving abilities. This is because mathematical learning props can facilitate students' understanding of learning mathematical concepts, visualize mathematical problems so that the relationship between elements in mathematical issues can be seen, encourage students to think critically and make mathematics learning more exciting and interactive. This shows that teaching props are essential for conducting research in mathematics education.

As time passes, more and more thesis research discusses using learning media. Many results from these studies are unknown to other students who want to research this topic, even though the media used tends to be the same. Therefore, this study aims to analyze the results of previous studies that examine teaching props on problem-solving abilities. For the research objectives to be achieved, the possible research questions are (1) based on the results of research that previous researchers have conducted, how big is the effect of teaching props on problem-solving abilities, (2) are the results of the research that has been conducted by them consistent with the general research hypothesis, namely that there is an effect of teaching props on problem-solving skills?

A summary of research results that discusses various problems with the learning media used is needed to answer the research questions. Summarizing previous research results can produce accurate and credible research (Cooper et al., 2019; Dinçer, 2018; McShane & Böckenholt, 2017) because it can show whether the research conducted is parallel to other studies. That meta-analysis method is needed to test whether studies with almost the same research focus have high parallelism, accuracy and credibility. Meta-analysis is a set of statistical methods for linking the quantitative results of several researchers to produce an overall summary of knowledge on a particular topic (Cooper et al., 2019; Gurevitch et al., 2018). The meta-analysis method can answer questions about the differences between the experimental and control groups based on research results that continue to increase yearly (Dinçer, 2018; Hedges & Olkin, 2014). Data analysis used to express research results is effect size. Effect size is used to find the magnitude of the teaching props' influence on students' problem-solving ability. The results of calculations using the effect size can be used as reinforcement for previous research.

2. METHOD

This study employed a quantitative approach focusing on meta-analysis. Meta-analysis is a study that can be calculated statistically by combining the results of two or more previous studies (Cooper et al., 2019; Hedges & Olkin, 2014). Meta-analysis summarizes the findings of several relevant studies to produce new developments for the research being studied or be used as reinforcement for the effects of previous research (Borenstein et al., 2009; Cleophas & Zwinderman, 2012; Gurevitch et al., 2018). The summary obtained from the results of previously conducted research aims to review, summarize, and evaluate the extent of the effects provided by the observed variables, the parallelism of the research that has been undertaken, and in the end, we can see the reliability of the results of the research that has been conducted (Gurevitch et al., 2018; Pigott & Moon, 2016).

The stages of meta-analysis research refer to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) stages, namely defining eligibility criteria, determining information sources, data selection, data collection, and data retrieval (Aravantinos et al., 2024; Tülübaş et al., 2023). The Prisma stages used in this study can be seen in Figure 1 for more details. After the data is selected, the next step is to conduct statistical analysis by determining the predetermined effect size and then drawing conclusions from the data obtained (Borenstein et al., 2009; Cooper et al., 2019; Gurevitch et al., 2018; Pigott & Moon, 2016).

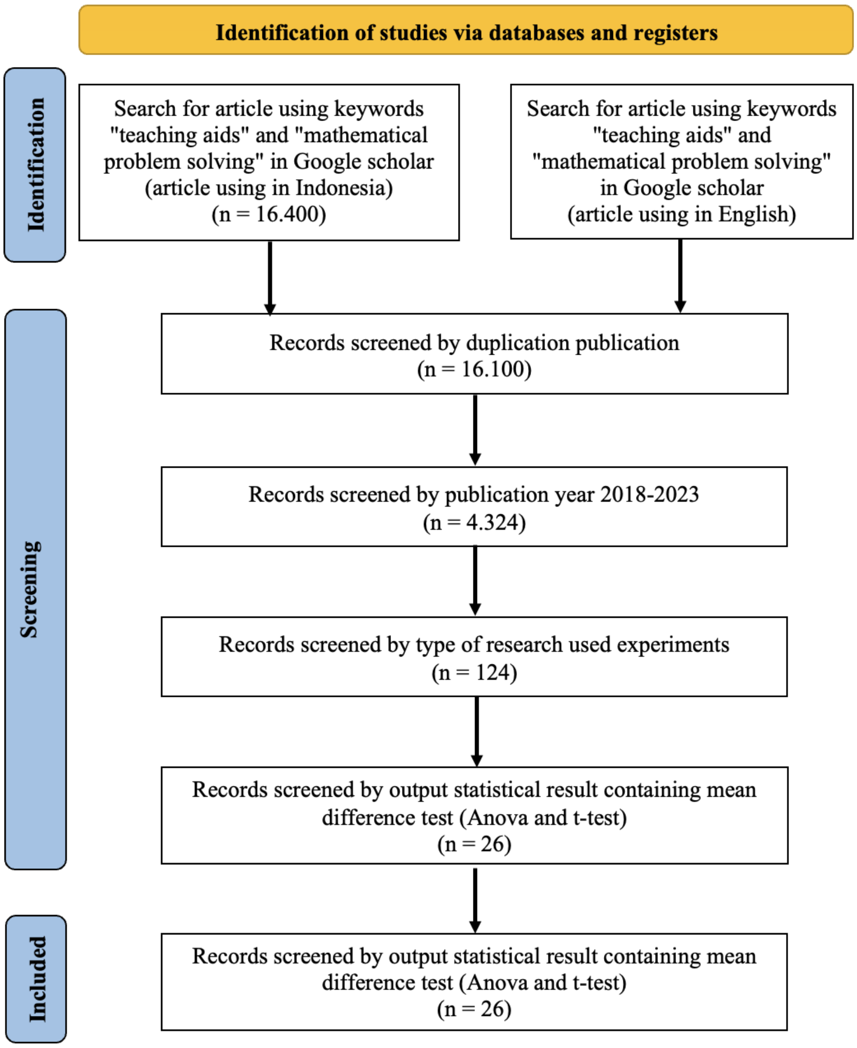

Figure 1. Diagram PRISMA for illustrating the screening process of papers the effect of teaching props on problem-solving ability

Determination of inclusion criteria in this research includes: (1) has been published in a journal or proceedings; (2) research results involve teaching props and problem-solving abilities; (3) the research results have F-test results, t-test, r, and sample size (n); and (4) research within the last five years, namely 2018-2023 (Widodo et al., 2023). The publication period between 2018-2023 was chosen because of the novelty of publications from research results conducted by researchers. Considering this, aspects of relevance, data quality, regulatory changes, and research trends and issues are better when compared to publications over 5 years old.

Research search results using Google Scholar worth keywords: “teaching aids”, “teaching props”, “mathematical problem solving”, and “teaching props”. However, this search engine is in the weak category, because Google Scholar indexes all published research results not only from journals or conference proceedings, but the thesis from students, research reports uploaded to campus repositories, and books are also available on this search engine. However, the Google Scholar search engine is specifically designed to broadly search for scientific literature without considering journals indexed by the Web of Science and Scopus. Previous research search results using Google Scholar obtained search results from more than 15,000 studies.

Based on the results of this study, 26 independent studies were taken as research subjects. Coding format characteristics provide information about the name of the researcher, year of publication, statistical test results, and sample size. The sample size used in the study classifies large and small sample size and small sample size. Large sample size is a study involving at least 30 subjects, and this is in line with the statement that the central limit theorem gives a good estimate of the sampling distribution of the mean for sample sizes of 30 or more (Kwak & Kim, 2017; Lakens, 2022). This is necessary to determine who conducted the study, when the independent study was published, how many statistical test results were obtained, and how large the sample size was used. The list of research used in this meta-analysis research can be seen in Table 1.

Table 1. Subject of research

Characteristic		f
Year of Publication	2018-2019	8
	2020-2021	9
	2022-2023	9
Level of Education	Primary School	5
	Junior High School	9
	Senior High School	11
	Higher Education	1
Sample Size	Large sample (≥ 30)	12
	small sample (< 30)	14
Techniques of Sampling	Random	17
	Purposive	7
	saturated	2

Data analysis is used in meta-analysis to calculate the effect size (Cumming, 2013). Effect Size is a method used to determine the magnitude of the influence of teaching props used in learning. The effect size calculation in this research is done by transforming the value from F to t and r and estimating the impact of sampling. The formula for calculating the effect size in this research is shown in Table 2 (Cooper et al., 2019; Widodo et al., 2023). The effect size calculation process was carried out using Microsoft Excel.

Table 2. Calculation of effect size from F-test, t-test, and r

Types of Statistical Tests	Formula of Effect Size	information
t-test	$ES = t\sqrt{\frac{1}{n_e} + \frac{1}{n_c}}$	t : The result of the t-test n_e : Sample size of the experimental group n_c : Sample size of the control group
r	$ES = \frac{2}{\sqrt{1-r}}$	r : The result of r
F-Test	$ES = F\sqrt{\frac{2}{n}}$	F : The result of F test n : Sample size

The results are based on calculating the effect size using a formula such as Table 2, then interpreted as shown in Table 3 (Wijaya et al., 2022).

Table 3. Effect size criteria

Range	Criteria
$-0.15 \leq ES < 0.15$	Very small effect
$0.15 \leq ES < 0.40$	Small effects
$0.40 \leq ES < 0.75$	Medium effect
$0.75 \leq ES < 1.10$	High effect
$1.10 \leq ES < 1.45$	Very high effect
$ES \geq 1.45$	extraordinary effect

3. RESULTS AND DISCUSSION

3.1. Results

Based on 26 previous independent studies used in this research, 26 pairs of comparisons were obtained and analyzed using meta to determine the effect of mathematics learning props on mathematical problem-solving abilities. The results of the effect size calculation using Microsoft Excel are shown in Table 4.

Table 4. Known Article Groups Statistical Results of the t-test, F-test, and r, as well as the Sample Size Used

Author (Year)	N	F	t	r	Effect Size
Hikmah (2018)	56	1.070	5.250	--	1.180
P. C. Sari et al. (2019)	64	22.116	4.703	--	5.529
Rahmadani and Sumardi (2019)	72	--	12.406	--	2.412
R. Y. Sari et al. (2019)	46	--	5.524	--	1.392
Hanifah et al. (2019)	60	7.502	0.533	--	1.937
Hendikawati et al. (2019)	53	0.735	1.724	--	0.406

Author (Year)	N	F	t	r	Effect Size
Safitri (2019)	60	--	-18.276	--	-3.946
Noviatika et al. (2019)	58	--	5.832	--	1.263
Hasibuan et al. (2019)	39	--	4.995	--	1.396
Septiani et al. (2020)	74	--	6.340	--	1.214
Juliantini et al. (2020)	46	1.070	3.910	--	0.985
Partayasa et al. (2020)	54	--	3.489	--	0.801
Hasibuan et al. (2020)	76	--	3.386	--	0.649
Harefa and La'ia (2021)	46	--	4.516	0.894	5.492
Tristanti et al. (2021)	62	--	18.409	--	3.900
Fadlilah et al. (2021)	64	1.245	3.376	--	0.844
Albab et al. (2021)	28	2.000	--	--	0.756
Putri and Putra (2021)	42	--	17.635	--	4.688
Berutu et al. (2022)	74	--	2.110	--	0.404
Mulyani et al. (2022)	42	1.520	11.510	--	3.060
Anggraeni et al. (2022)	64	1.071	1.997	--	0.415
Astuti et al. (2022)	60	--	4.390	--	0.948
Pratidiana et al. (2022)	40	24.032	4.902	--	7.600
Yuliana et al. (2022)	52	1.048	5.795	--	1.359
Handayani et al. (2023)	50	28.583	4.803	--	8.084
Hasyanah et al. (2023)	62	41.484	10.847	--	10.894
Summary	1444	--	--	--	63.662
Average	--	--	--	--	2.449

Based on calculations from Table 4, the average effect size is 2.449, and the effect size is at an extraordinary level.

3.2. Discussion

Education is a conscious, planned effort to create a pleasant atmosphere for the learning process so that students actively develop their potential for religious and spiritual strength, self-control, personality, intelligence, noble morals, and the skills needed by themselves and society. With education, it is hoped that it can give birth to the nation's next generation with intelligent and qualified individuals. This means that the nation's next generation will be a generation that can make the best use of existing progress. Education will not progress if the education system is not appropriate. This follows the educational conditions in Indonesia. Education in Indonesia needs to be of better quality, which causes it to lag behind other countries. Based on existing problems such as an inadequate education system and other central issues, cooperation is needed from the government, teaching staff, students, parents, and the community. Suppose there is one party that cannot work together well. In that case, the goal of quality education will not produce results, and the quality of education in Indonesia will continue to decline because education can improve the quality of a nation (Asiyai, 2015; Saidek et al., 2016).

Problem-solving skills are a learning process that awakens students to play an active role in receiving and responding to questions submitted well and overcoming difficulties in solving a problem (Harisman et al., 2020; Murtafiah et al., 2024; Niu et al., 2022; Steyn & Adendorff, 2020). Problem-solving skills are also one of the abilities students must have after studying mathematics (Özreçberoğlu & Çağanağa, 2018; Wijayanti et al., 2022). Problem-solving is seen as applying concepts and skills, whereas problem-solving usually involves some combination of ideas and skills in a new situation (van Merriënboer, 2013).

Students can use Polya problem-solving steps to find solutions with several steps, namely understanding the problem, which means students identify the information contained in the issues and questions; drawing up a plan, which means students connect previous knowledge with the information contained in the situation and what is asked in the question (Erbilgin & Macur, 2022). Questions and carrying out projects, students do calculations and check again, which means they make corrections about the problems they have obtained (Arbo & Ching, 2022; Chidyaka & Nkhata, 2019). The problem of mathematics learning so far has been that the ability to solve mathematical problems is not optimal. As reported by PISA through the OECD in 2018, it was found that the average mathematics score of students in Indonesia reached 379 with an OECD average score of 487, and in 2022, the average mathematics score of students in Indonesia fell by 16 points (Kusmaryono & Kusumaningsih, 2023; Nugrahanto & Zuchdi, 2019; OECD, 2019, 2023). In addition, several independent studies conducted in several regions in Indonesia also reported almost the same preliminary studies. These results indicate that the student's skill to solve mathematical problems is still less than satisfactory (Praekhaow et al., 2021; Siagian et al., 2019).

The result of an independent study reports that one way to improve mathematical problem-solving skills is to use teaching props (Hakim et al., 2019; Siagian et al., 2019; Ulandari et al., 2019). The many previous studies that focus on improving the ability to solve problems using teaching props have led to the need for a summary of similar studies to review and evaluate the extent of the influence given by the observed variables and the parallelism of the research that has been done.

This meta-analysis study aims to analyze the influence of teaching props on problem-solving ability using data from articles published in journals and national proceedings. As previously stated, meta-analysis research can be used to review and evaluate the extent of the influence given by the observed variables. Therefore, this meta-analysis study supports or refutes previous studies' results on teaching props that positively change students' problem-solving abilities. This study determines whether teaching props should be developed to improve problem-solving skills. The calculation used in this meta-analysis study is effect size.

Effect size is used to show the magnitude of the influence of the relationship between two variables, namely the independent and dependent variables (Ferguson, 2016). In this case, the independent variable studied is the teaching props, while the dependent variable is the student's problem-solving abilities. Calculating the effect size of each study can produce the magnitude of the effect of a treatment. By collecting 26 articles that are related to teaching props to problem-solving abilities, researchers can obtain research results.

The results of meta-analysis calculations using effect size show that the length of each study varies. In Table 4, there is 1 data with a negative value, which shows that the control group, which received learning without teaching props, was superior to the experimental group, which received learning with props. On the other hand, 25 positive effect sizes showed that the experimental group was unique to the control group. This research offers various results in applying learning with teaching props to students' problem-solving abilities. The results of the meta-analysis calculations can produce new developments for the research being studied and can be used as reinforcement for previous research.

Based on the effect size calculation, the result was 2.449 with an extraordinary category at the interval ES≥1.45. The term "extraordinary category" implies that an effect size of 2.449 is not just statistically significant but is also considered immense practical significance. In this case, an effect size above 1.45 is extraordinary, indicating a robust and noteworthy result. Therefore, it can be concluded that teaching props positively affects students' problem-solving abilities. Thus, this research shows that teaching props can improve students' problem-solving skills. The enormous effect size of 2.449 will likely have important implications in mathematics education. It suggests how using teaching props affects students' problem-solving abilities and potentially warrants attention from researchers, policymakers, or educational practitioners.

Several studies related to teaching props and problem-solving abilities, including research related to the influence of Edmodo on problem-solving skills, obtained an average result with the use of props 67.27, which was higher than without the use of props, which brought an average of 66.73 (Hanifah et al., 2019). On the other hand, there is research on using the Mobile Pocket Book to improve problem-solving abilities (Noviatika et al., 2019). Another example of teaching props is the *Gagung Duran* Application for problem-solving skills (Albab et al., 2021) and audio video for problem-solving abilities (Harefa & La'ia, 2021).

Teaching props assist the learning process so the message can be conveyed and received well and run effectively and efficiently (Hasibuan et al., 2019). Teaching props can be designed and developed according to the conditions and situations in learning. Thus, teachers are required to be able to create teaching props to improve the learning process. It is hoped that students can use teaching props designed or developed by teachers for independent learning.

Teaching props in the learning process effectively and efficiently achieve the desired learning objectives (Ali et al., 2013; Modebelu & Duvie, 2012). Props are used in the learning process to improve children's motor sensors, increase interaction between teachers and students, and make students more focused on learning (Lee et al., 2019). Props can contain questions that students must solve. These questions are arranged in problem-solving stages so students can practice solving problems. Thus, teaching props can be used to improve problem-solving abilities.

Based on the results of previous research, it is still necessary to summarize the research results related to teaching props on problem-solving skills. These studies have not been able to provide an overview of the influence of teaching props on problem-solving skills. Therefore, this research was conducted using meta-analysis to determine the magnitude of the impact of teaching props on problem-solving skills. In addition to knowing the magnitude of the effect or influence of teaching props on the ability to solve mathematical problems, meta-analysis research can also see the consistency of research results with the general research hypothesis, namely that there is an effect of teaching props on the ability to solve mathematical problems. The magnitude of the impact was explained in the previous section, which is 2.449, an extraordinary category. This shows that teaching props have a very extraordinary effect on the ability to solve mathematical problems.

Besides that, the meta-analysis results in this research show a positive influence between teaching props and students' problem-solving skills. This condition indicates that this research is consistent with the results of research that has been carried out so far and the general research hypothesis, namely that there is an effect of teaching props on problem-solving ability that has been consistently proven. These results agree with a previous study stating that learning assisted by teaching props, for example, Geogebra, can improve problem-solving skills (P. C. Sari et al., 2019). Other research shows a positive influence on flipped classroom teaching (Pratidiana et al., 2022). Further research also shows increased students' problem-solving abilities with the help of clinometer teaching props (Rahmadani & Sumardi, 2019). Likewise, another study states that the guided inquiry learning model assisted by teaching props influences problem-solving skills (Septiani et al., 2020).

4. CONCLUSION

Based on the results of the analysis, it can be concluded that this research can make teaching props a learning medium that can foster student motivation and improve students' problem-solving abilities. Teachers can use teaching props such as digital props (i.e. *gagung duran*, *aplikasi bangun ruang* or *abaru*), physical manipulative props (i.e. *dakonmatika*), and others. These props, empirically and practically, can improve the quality of learning and students' problem-solving skills. Students can use teaching props independently to increase learning independence and improve problem-solving skills.

In this study, twenty-six (26) studies were analyzed. The calculation of the effect of teaching props on students' problem-solving abilities is 2.449. This shows that the influence of teaching props on students' problem-solving skills is in the "extraordinary" category. In future research, researchers need to examine the development of teaching props adapted to the curriculum, learning model, characteristics, and environment of students.

Based on the results and discussion presented, it was found that using props in learning was more effective on problem-solving skills than not using props in the learning process on students' problem-solving skills. This research provides participation in research related to teaching props on students' problem-solving abilities. One of the most essential contributions in research related to visual props to problem-solving abilities is the positive influence of visual props on problem-solving skills based on research findings. Thus, the results of this study indicate that the relationship between teaching props and students' problem-solving skills has a positive influence.

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Declarations

Author Contribution	: SAW: Conceptualization, Investigation, Methodology, Writing - original draft, and Writing - review & editing; YN: Formal analysis, and Writing - original draft; SMC: Supervision, and Writing - review & editing; NF: Supervision, Validation, and Writing - review & editing; FS: Formal analysis, and Supervision; WM: Supervision, and Validation; DFP: Validation, and Writing - review & editing.
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