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Enhancing students' problem-solving skills through the HOPS model: Evidence of practicality and effectiveness

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Abstract
This study highlights the weak mastery of problem-solving skills among students. This issue occurs because established learning models, such as PBL, still have gaps that need to be addressed in training those skills. Efforts to fill this research gap are carried out through the development of a learning model. The objective is to examine the practicality and effectiveness of the Heuristic Oriented Problem Solving (HOPS) model in enhancing the problem-solving skills of students in elementary teacher education programs. The study employed a pre-experimental design using a one-group pretest-posttest approach involving 47 students from two randomly selected classes at a university in Surabaya. Data were collected through observation sheets, problem-solving tests, and student response questionnaires. The results indicate that the HOPS model is highly practical, as reflected by an average implementation score of 3.99 (very good category). Its effectiveness is supported by four findings: (1) an average N-Gain score of 0.87, categorized as "high," indicating substantial improvement in students' problem-solving skills; (2) a significant difference between pre-test and post-test scores based on the paired t-test ($p < 0.05$) with a strong effect size ($d = 4.61$); (3) no significant difference between the two classes based on the independent t-test ($p > 0.05$), indicating consistent improvement; and (4) highly positive student responses ranging from 91% to 97%, categorized as "very effective." In conclusion, the HOPS model is both practical and effective in improving problem-solving skills and can serve as an alternative instructional model in higher education contexts. The implication is that the HOPS model has the potential to enhance problem-solving skills for students in elementary teacher education programs in various science-related courses.

Introduction

The 21st century has ushered in an era of globalization that has a wide-ranging impact on human lifestyles (Anggraeni et al., 2023; Halili et al., 2022). In this era, the ease of access to technology has created effortless connections between people around the world, triggering changes in human life across various fields (Levin & Mamlok, 2021; Molino et al., 2020). Changes also make life more chaotic, uncertain, complicated, and unclear (Latha & Christopher, 2020; Seow et al., 2019), which makes it harder to make decisions and adapt to different parts of life. Based on these factors, problem-solving skills have become one of the essential 21st century skills that students must master (Riyadi et al., 2021; Yoon et al., 2020), especially to tackle various complex problems encountered in daily life (Martaningsih et al., 2022; Wang, 2021).

In the workplace, problem-solving skills have become the most in-demand of the 21st century (Rios et al., 2020). This is in line with the World Economic Forum's (2023) report, which states that problem-solving skills are becoming the most important and are experiencing increased demand in the

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workforce over the next five years until 2027. However, research findings indicate that students' mastery of these skills remains low (Franestian et al., 2020; Ghofur et al., 2023b). Several countries also suspect low problem-solving skills among students. Based on the OECD report (2023), there are at least 43 countries where students' mastery of science is below level 4, while to master problem-solving skills, students must be at least at science mastery level 4, with a score range between 485 and 559. Additionally, the report also reveals that based on PISA study results from 2006 to 2022, students' mastery of science in Indonesia is still at level 2, with the lowest score being 382 in 2012 and the highest score being 403 in 2015. This indicates that students' mastery of problem-solving skills remains a serious issue in various countries, including Indonesia.

For several decades, the PBL model has been considered a reliable learning model for training problem-solving skills (Magaji, 2021; Valdez & Bungihan, 2019). However, this learning model still has limitations in training students' problem-solving skills (Kurniawan & Sofyan, 2020; Valdez & Bungihan, 2019). Based on the preliminary study conducted by Ghofur et al. (2023b), it is known that there are at least two limitations of the PBL model in training students' problem-solving skills. First, without a thorough mastery of prior knowledge or basic concepts, the PBL model cannot fully enhance students' problem-solving skills. Second, the PBL model does not yet meet the pedagogical principles as a problem-based learning model. The first finding is in line with the research conducted by Lonergan et al (2022) and Mabley et al (2020), indicating that mastery of basic concepts or prior knowledge of students related to the topic being studied is critical in problem-solving learning (Dolmans, 2019; Zheng et al., 2023).

The study results also indicate that the PBL model is less effective in enhancing students' mastery of theories related to the topics studied compared to conventional learning (Marcinauskas et al., 2024), has a small impact on students' knowledge retention (Solomon, 2020), is less effective in improving students' mastery of conceptual knowledge (Shishigu et al., 2018), and is less effective in enhancing students' conceptual understanding (Tawfik et al., 2020). These findings indicate that the PBL model is less suitable for the goal of mastering a particular knowledge or basic concept. This is because, in the PBL model, the mastery of relevant knowledge or basic concepts is actually used to solve the presented problems, which may lead to superficial understanding rather than deep mastery of the theories and concepts involved (Amanda et al., 2021; Naji et al., 2020).

Based on several studies, it is known that the basic concepts possessed by students play an important role in the learning process, including contributing to improved problem-solving (Komarudin et al., 2020) influencing the increase in student motivation and metacognition (Pozas et al., 2020) serving as a reliable predictor of performance and learning (Simonsmeier et al., 2022) enhancing students' understanding and systemic thinking abilities (Muhammed et al., 2022) strengthening students' scientific reasoning (Susilawati et al., 2021) and increasing student engagement in quality learning processes (Dong et al., 2020). However, the PBL model as formulated by Arends (2015) has not yet emphasized the mastery of basic concepts or prior knowledge, which is a limitation that needs to be addressed.

It is known that the syntax of the PBL model, as formulated by Arends (2015) consists of five syntaxes. Specifically, 1) orienting students to the topic; 2) organizing students to learn; 3) guiding individual and group investigations; 4) generating and presenting work findings; and 5) evaluating and analyzing problem-solving procedures. Based on these five syntaxes, no activities related to formulating hypotheses and reflecting on problem-solving processes were found. However, these activities are critical in training students' problem-solving skills (Kerr, 2016; Woolfolk, 2021). This conclusion is because empirically, students who can correctly hypothesize their problems are the most efficient in solving them (Blackburn & Robinson, 2016; Kuang et al., 2022). Meanwhile, based on Scott's (2017) explanation, it is known that reflection is a necessary part of the PBL model learning process, as it is a mechanism through which students can flexibly build their knowledge base. Therefore, the absence of these two activities in PBL model learning is certainly not in line with the pedagogical principles of the learning model itself in training students' problem-solving skills (Dabbagh, 2019; Ghofur et al., 2023b), making this a limitation of PBL that needs to be addressed.

The HOPS (Heuristic Oriented Problem Solving) model is a learning model developed by addressing the weaknesses of the PBL model in terms of students' mastery of prior knowledge and the fulfillment of problem-solving pedagogy principles (Ghofur et al., 2023a). This learning model was developed by adding new learning phases, namely, 1) the exploring phenomenon phase to strengthen the prior knowledge needed in the problem-solving process and 2) the hypothesis formulation and reflection phase to meet the principles of problem-solving pedagogy. In this case, the HOPS model syntax was developed based on the proposals of Dolmans (2019) and Ghofur et al (2023b) to adopt, reorganize, and add new syntax to the PBL model syntax to fully train students' problem-solving skills. The syntax of the HOPS model produced based on these proposals is as follows: 1) problem, 2) exploring phenomenon, 3) formulating hypothesis, 4) experimenting, 5) communicating, and 6) evaluating and reflecting. The purpose of this research is to determine the practicality and effectiveness of the HOPS model in training students' problem-solving skills.

Methods

This research is an experimental study using a one-group pre-test and post-test design, namely, O1 X O2 (Astutik & Prahani, 2018; Fraenkel et al., 2012). In this case, before the implementation of the HOPS learning model, each student was given a pre-test using complex problem-solving skill questions. Thereafter, the learning was conducted over four sessions in the basic science concepts course, followed by a post-test. This study involved 47 students in elementary teacher education programs at one of the universities in Surabaya, with details for 22 students from class A and 25 students from class B. Both classes were selected randomly.

In this study, learning is conducted using educational tools in the form of semester learning plans, HOPS model-based workbooks, ICT-based learning media, and problem-solving skill questions. Before the research was conducted, all the learning devices to be used were at least declared valid and reliable based on the assessment of three experts. The results of the validation of the learning devices are shown in Table 1.

Table 1. Results of the HOPS Model Learning Device Validation

Validation Aspects	Average Score	Category	Reliability
Semester Learning Plan	3,56	Highly Valid	Reliable
HOPS model-based workbooks	3,75	Highly Valid	Reliable
Problem-solving skill questions	3,79	Highly Valid	Reliable

This study focuses on the HOPS model's practicality and effectiveness for teaching problem-solving skills. The data analysis used is as follows.

The practicality of the HOPS model

The level of practicality of the HOPS model in this study is determined through the implementation of the learning model. The observation of the implementation of the learning was conducted by three observers using an observation sheet. The scores obtained were then converted into qualitative data on a four-point scale (Hariadi et al., 2021). The interpretation of the practicality level of the HOPS model is based on the average score (P) on a scale of 1 to 4. In this case, the practicality of the developed learning model is categorized as "Poor" if it shows a score between 1.00 and 1.79. It is then categorized as "Fair" if the score ranges from 1.80 to 2.29 and "Good" if the score ranges from 2.30 to 3.39. Meanwhile, the learning model is categorized as "Exceptional" if the average score ranges from 3.30 to 4.00 (Hasyim et al., 2024).

The effectiveness of the HOPS model

This study evaluates the effectiveness of the HOPS model through three aspects. First, this step is based on the calculation results or the acquisition of N-Gain scores. The calculation is performed on the pre-test and post-test scores of each student using the equation proposed Ghofur et al. (2025). Based on Hake's (1999) explanation, it is known that there are three categories for interpreting N-Gain values, namely, 1) if the average N-Gain obtained is less than 0.3, it falls into the low category; 2) if the average N-Gain is between 0.3 and less than 0.7, it falls into the medium category; and 3) if the average N-Gain is greater than or equal to 0.7, it falls into the high category. In this study, the HOPS model is said to be effective in training students' problem-solving skills if the average N-Gain obtained is at least in the moderate category (Ghofur et al., 2025; Hasyim et al., 2024).

Second, based on the significance of the increase in pre-test to post-test values obtained through statistical tests. In this case, the statistical analysis conducted for normally distributed data used the paired t-test data and for non-normally distributed data used the Wilcoxon test (Suprapto et al., 2025). The testing was conducted using SPSS version 22 with a significance level of 0.05. In this study, effect size calculations were also conducted. The purpose is to determine the extent of the impact of the HOPS model on the improvement of students' problem-solving skills. Effect size is a method used to measure the effectiveness of a study (Hasyim et al., 2024; Lestari et al., 2021). In this case, the magnitude of the treatment effect is determined through the calculation of effect size (d). If the calculation results show a value greater than 1.00, it can be categorized as a strong effect. Furthermore, if the value is between 0.51 and 1.00, it is categorized as a moderate effect, and if the value obtained is between 0.21 and 0.50, it is categorized as a modest effect. Meanwhile, if the value shows 0.00 to 0.20, it can be categorized as a weak effect (Alwahaibi et al., 2020; Pallant, 2020).

Third, the improvement in students' problem-solving skills in two classes was consistently observed through statistical tests. In this case, the statistical analysis was conducted using an independent t-test for normally and homogeneously distributed data and the Mann-Whitney test for non-normally and/or non-homogeneously distributed data (Chicco et al., 2025; Curtis, 2024). The testing was conducted using SPSS version 22 with a significance level of 0.05.

Fourth, based on student responses to the HOPS model learning. In this case, student responses are used to understand students' opinions on HOPS model learning along with its supporting learning devices. The obtained data is then converted into percentages and interpreted based on the existing criteria. If the percentage obtained ranges from 0% to 20%, it is categorized as ineffective, and if the percentage is between 21% and 40%, it is categorized as less effective. Next, if the percentage obtained shows 41% to 60%, it is categorized as fairly effective, and if it shows 61% to 80%, it is categorized as effective. Meanwhile, if the percentage obtained shows 81% to 100%, it is categorized as very effective (Wahyuni et al., 2020).

Results

The following are the research results related to the practicality and effectiveness of the HOPS model obtained through learning trial activities.

The practicality of the HOPS model

The practicality of the HOPS model in this study is obtained through the implementation of learning. The implementation of learning is shown in Table 2.

Tabel 2. Implementation of the HOPS model

No.	Phases	Score	Category
1	Problem	4	Exceptional
2	Exploring phenomenon	4	Exceptional
3	Formulating hypothesis	4	Exceptional
4	Experimenting	4	Exceptional
5	Communicating	3,94	Exceptional
6	Evaluating and reflecting	3,97	Exceptional
	Average	3,99	Exceptional

The effectiveness of the HOPS model

Table 3 shows the average pre-test scores, average post-test scores, and the N-Gain calculation results for the two target classes of the study.

Table 3. Average test scores and N-Gain

Aspect	Class A	Class B
Number of students	22	25
Average Pre-test Score	38,3	44,6
Average Post-test Score	90,8	93,6
Average N-Gain	0,85	0,88
Average N-Gain for the two target classes	0,87	
Category	High	

Table 4 shows the N-Gain calculation results for each problem-solving skill indicator trained in this study.

Table 4. N-Gain calculation results for each indicator

No.	Problem-Solving Skills Indicators	Class A		Class B	
		N-Gain	Category	*N-Gain*	Category
1.	Identifying the problem	0,87	High	0,89	High
2.	Formulating the problem.	0,98	High	0,89	High
3.	Planning to solve the problem.	0,95	High	0,83	High
4.	Defining the purpose of the problem-solving plan.	0,88	High	0,95	High
5.	Exploring possible strategies.	0,69	Medium	0,68	Medium
6.	Formulating a hypothesis.	0,87	High	0,80	High
7.	Carry out the problem-solving plan or experiment.	0,98	High	0,78	High
8.	Analyzing the data.	0,82	High	0,88	High
9.	Drawing a conclusion	0,93	High	0,98	High
10.	Reflecting on problem-solving.	0,88	High	0,88	High

Table 4 shows that the average N-Gain value obtained is 0.87. This value falls into the high category. This indicates that the average post-test score is higher than the pre-test score in the two target classes of the study. Meanwhile, Table 4 shows the N-Gain values obtained for each indicator of problem-solving skills that were trained. The ten indicators fall into the moderate to high category. Tables 5 and 6 present the results of the normality and homogeneity tests, respectively.

Table 5. Normality test results

Class	Shapiro-Wilk Test			Conclusion
	Data	Statistics	Sig.	
Class A	*N-Gain*	0,970	0,713	Normal
Class B	*N-Gain*	0,934	0,107	Normal

Table 6. Homogeneity test results

Class	Levene's test		Conclusion
	Data	Sig	
A dan B	*N-Gain*	0,823	Homogeneous

Table 5 shows that the significance value for Class A is 0.713 and for Class B, it is 0.107. Meanwhile, Table 6 shows a greater significance value of 0.823. This indicates that these values are greater than 0.05, meaning the data are normally distributed and homogeneous. Therefore, the data analysis used in this study is parametric statistics. In this study, the paired t-test and effect size were used to determine the increase in pre-test to post-test scores after the HOPS model learning was implemented. Where Table 7 shows the results of the paired t-test, Table 8 shows the results of the effect size calculation.

Table 7. Results of the Paired t-test

Statistical test	Data	Sig.	Description
Paired t-Test	Pre-test and post-test	0,000	There is a difference.

Table 8. Effect size

Statistical test	Effect Size	Description
Paired t-Test	d = 4,61	Strong Effect

Based on Table 7, it was found that there is a significant difference between the pre-test and post-test scores of the two classes, with a significance value of less than 0.05. Based on these values and the N-Gain findings presented in Table 9, the results indicate that students' problem-solving skills improved after the implementation of the HOPS model. The effect size calculations in Table 8 also show that the HOPS model has a very strong effect on improving students' problem-solving skills. To determine whether there is a difference in the improvement of students' problem-solving skills between the two classes, an independent t-test was conducted. Table 9 shows the results of the test.

Table 9. Results of the Independent t-test

Statistical test	Data	Sig.	Description
Independent t-test	N-Gain	0,194	There is no difference

The significance value of 0.194, as shown in Table 9, indicates that there is no difference in N-Gain between the two classes targeted in the study. This means that students in both classes experienced the same improvement in problem-solving skills. Thus, these findings indicate a consistent improvement in students' problem-solving skills in each class. Meanwhile, Figure 1 shows the students' responses indicating the effectiveness of the HOPS model.

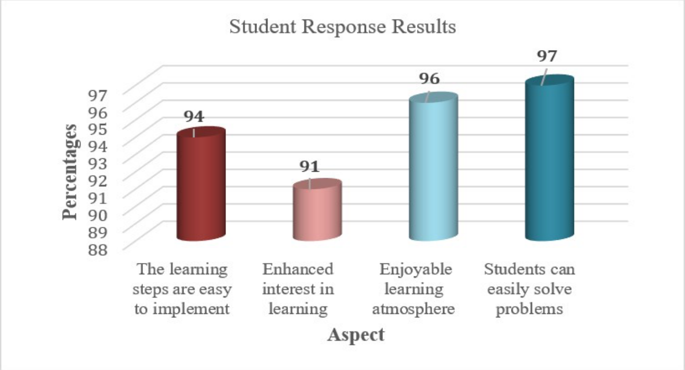

Figure 1. Student response results after the application of the HOPS model

Figure 1 displays the findings from student responses after the implementation of the HOPS model. The students' responses encompass four aspects that serve as indicators of the effectiveness of the HOPS model, namely, 1) the learning steps are easy to apply; 2) it increases learning interest; 3) it creates an enjoyable learning atmosphere; and 4) it facilitates students in problem-solving. It is known that the average student's responses ranged from 91% to 97% in the category of 'very effective'. This means that according to the students, the HOPS model is very effective in training students' problem-solving skills.

Discussion

The HOPS model is a learning model designed to train students' skills of problem-solving. Practicality and effectiveness are two aspects investigated in this study. In this case, it is known that the practicality of a learning model is based on the successful implementation of each learning phase, while the effectiveness of a learning model is based on the achievement of learning outcomes and students' responses to the conducted learning (Hasyim et al., 2024; Lestari et al., 2021; Siswanto et al., 2018). Table 6 shows that the six phases of the HOPS model, which include (1) problem-solving, (2) exploring phenomena, (3) formulating hypotheses, (4) experimenting, (5) communicating, and (6) evaluating and reflecting, have been very well implemented in all classes at each research target school. This conclusion can be seen from the average scores ranging from 3.94 to 4, where the average scores for the implementation of the six learning phases fall into the 'very good' category. This evidence indicates that the lecturers can implement each phase of learning according to the plan outlined in the semester lesson plan. This finding indicates the ease with which lecturers can apply the HOPS model. The ease of implementation indicates that the HOPS model meets the practical criteria as a teaching model for training students' skills of problem-solving.

In this study, the effectiveness of the HOPS model can be determined through four aspects. First, this is based on the acquisition of N-Gain scores. Table 3 shows that the average N-Gain score falls into the high category. The obtained category indicates that all students in each school have experienced an increase in pre-test to post-test scores (Lusiana & Andari, 2020; Putri et al., 2019). This result indicates that there has been an improvement in problem-solving skills after students participated in learning using the HOPS model. Moreover, based on the N-Gain calculations for the ten problem-solving skill indicators practiced, as shown in Table 8, the results fall into the moderate to high category. This means that the application of the HOPS model can improve students' achievements in the ten indicators of skills. Thus, we can declare the HOPS model effective in training students' problem-solving skills based on this first aspect.

Second, the effectiveness of the HOPS model can be determined through statistical tests that show an increase in pre-test to post-test scores. Table 7 shows a significant difference in pre-test and post-test scores obtained through paired t-tests. The difference in scores indicates an improvement from pre-test to post-test. This means that the HOPS model contributes to improving students' problem-solving skills. In this study, the HOPS model has a very strong influence on enhancing students' problem-solving skills. This can be seen through the effect size calculation of the learning model (Table 8). Thus, the HOPS model can be declared effective in training students' problem-solving skills based on this second aspect. Third, the effectiveness of the HOPS model can be determined through statistical tests that illustrate the consistency of the improvement in students' problem-solving skills. Table 9 shows that there is no significant difference in N-Gain scores. This indicates that all students in the two classes at the school experienced the same improvement skills in problem-solving.

The six phases of the HOPS model syntax closely relate to the improvement of students' problem-solving skills in all classes of this study. The first phase is the problem. The goal of this phase is to motivate students by presenting authentic problems that capture their attention and encourage them to learn and solve these problems. For the purpose of motivation, the HOPS model is based on the ARCS theory, which states that to foster curiosity and interest in learning, students must pay attention (Li, 2022; Mei et al., 2025). The next goal is to train students to identify and formulate problems. For this second goal, the HOPS model is based on the top-down theory, which states that learning can begin with the presentation of complex problems that are then solved by students (Çibukçiu, 2025; Slavin, 2018), and the complex cognitive theory, which states that in learning, students think more in a learning environment that can stimulate and encourage independent thinking (Mamun & Lawrie, 2024; Woolfolk, 2021). Meanwhile, empirical support for this phase is based on the research findings of Yunus et al. (2021), which found that students with high motivation have excellent problem-solving abilities. Additionally, the research findings of Erawarni & Yulianti (2021) found that students at the concrete and formal operational stages are able to identify and formulate problems well based on the phenomena or problems presented.

The second phase is exploring phenomena. The objectives of this phase are the following: 1) to facilitate students in exploring phenomena from various sources to strengthen their prior knowledge. For this purpose, the HOPS model is based on the theory of seamless learning, which reveals that the use of learning resources in exploring phenomena emphasises the use of relevant information technology integrated into learning activities (Chettaoui et al., 2023; Wong & Looi, 2019), and Piaget's constructivist theory, which states that knowledge can be constructed by transforming, organising, and reorganising prior knowledge (Brand et al., 2025; Woolfolk, 2021) and 2) to train students in planning, strategising, and defining problem-solving goals. For this purpose, the HOPS model is based on constructivist and complex cognitive theories, which state that the activity of planning problem-solving is viewed as a systematic planning construction and falls within the realm of higher-order thinking (Khaparde, 2019; Santrock, 2018). Meanwhile, empirical support for this phase is based on the research findings of Komarudin et al. (2020), which found that students' prior knowledge effectively contributes to improving their skills in problem-solving.

The third phase is formulating hypotheses. The goal of this phase is to train students to formulate hypotheses. For this purpose, the HOPS model is based on two theories: 1) Piaget's cognitive development theory, which states that the characteristics of an individual at the formal operational stage are the ability to think combinatorially, solve problems, and hypothesise (Cerovac & Keane, 2025; Eggen et al., 2016) the constructivism theory, which states that in formulating hypotheses, students can use their prior knowledge to construct phenomena that are the main issues in learning (Bittermann et al., 2023; Schneider & Simonsmeier, 2025). Meanwhile, empirical support for this phase is based on the research findings of Mashluhah et al. (2019), which found that the activity of formulating hypotheses as part of the learning phase contributes to improving students' skills in problem-solving.

The fourth phase is experimenting. The goal of this phase is to train students in hypothesis testing activities. For this purpose, the HOPS model is based on two theories, namely, 1) Experiential Learning, which states that students' learning experiences can be obtained through experimental investigation (Lehane, 2020; Morris, 2020) Piaget's constructivist theory, which states that knowledge is built through exploration and discovery (Emden, 2021; Martín-Lucas & Dujo, 2023). Meanwhile, empirical support for this phase is based on the research findings of Khaparde (2019), which found that laboratory experiment activities can foster problem-solving skills.

The fifth phase is communicating. The objectives of this phase are 1) to facilitate students in group discussions to analyse data and generate problem-solving ideas, and 2) to train students in class discussions to communicate problem-solving ideas and draw conclusions. For both objectives, the HOPS model is based on Vygotsky's social constructivist theory, which states that reasoning, understanding, and critical thinking derived from social interactions can be internalised by individuals (Nagpal et al., 2025; Robey et al., 2022). Meanwhile, empirical support for this phase is based on the research findings of Syarifudin et al. (2019), which found that the presentation of problem-solving ideas and information-sharing activities used in problem-solving are demonstrated by students' verbal activities during discussion sessions.

The sixth phase is evaluating and reflecting. The purpose of this phase is to train students to reflect on the problem-solving processes they have undertaken. For this purpose, the HOPS model is based on theory of experiential learning, which states that in learning, students must be involved in new experiences and reflect on those experiences from different perspectives (Hmoud et al., 2025; Lehane, 2020). Meanwhile, empirical support for this phase is based on the research findings of Gayathri et al. (2021), which found that reflection activities can help students contemplate the entire process of self-introspection and understand mistakes made during learning.

Fourth, the students can determine the effectiveness of the HOPS model through their responses. Based on the results of the student response questionnaire in Figure 1, it was found that 94% of students stated that the steps of the HOPS model are easy to implement, 91% of students stated that the HOPS model can increase learning interest, 96% of students stated that the HOPS model provides a pleasant learning atmosphere, and 97% of students stated that the HOPS model facilitates problem-solving. In this case, the four aspects of student responses are indicators of the effectiveness of the HOPS model. All the percentages obtained fall into the very effective category. This means that based on the students' responses, the HOPS model is declared very effective in training students' problem-solving skills.

Based on these findings and discussions, it indicates that the HOPS model is proven to be practical and effective in training students' problem-solving skills in the basic science concepts course. The results of this study demonstrate that, both theoretically and empirically, educators can use the HOPS model to train problem-solving skills at the higher education level.

Conclusion

The purpose of this study is to look at the practicality and effectiveness of the HOPS model for teaching problem-solving skills to prospective elementary school teacher trainees. The results of the study show that the HOPS model has proven to be practical. This is evident from the average implementation score of 3.99, which falls into the very good category. The HOPS model also proved effective when viewed from four aspects. First, the average N-Gain score of 0.870 falls into the high category. Additionally, the N-Gain review indicates that there is an improvement in student achievement across ten indicators of problem-solving skills, which fall within the medium to high category in all classes. Second, the paired t-test with a significance value of less than 0.05 indicates an improvement in students' problem-solving skills. Furthermore, the effect size calculation shows a forceful influence of the HOPS model in training students' problem-solving skills. Third, the independent t-test shows a significance value of 0.194, indicating a similar improvement in problem-solving skills in both classes and demonstrating consistency in that improvement. Fourth, student responses were positive, indicating ease in implementing the HOPS model learning steps (94%), increased student interest (91%), a pleasant learning atmosphere (96%), and ease in problem-solving (97%). Therefore, the HOPS model has been theoretically and empirically proven to enhance the problem-solving skills of prospective pre-service primary school teachers. The results of this study imply that the HOPS model can be used as an alternative learning model to train problem-solving skills in higher education students.

References

Alwahaibi, I. S. H., Al-Hadabi, D. A. M., & Al-Kharousi, H. A. T. (2020). Cohen's criteria for interpreting practical significance indicators: A critical study. *Cypriot Journal of Educational Sciences*, *15*(2), 246–258. https://doi.org/10.18844/cjes.v15i2.4624

Amanda, F. F., Sumitro, S. B., Lestari, S. R., & Ibrohim, I. (2021). Analysis of the Relationship Between Concept Mastery and Problem-Solving Skills of Pre-Service Biology Teachers in Human Physiology Courses. *Jurnal Pendidikan Sains Indonesia*, *9*(3), 421–432. https://doi.org/10.24815/jpsi.v9i3.19956

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic Review of Problem Based Learning Research in Fostering Critical Thinking Skills. *Thinking Skills and Creativity*, *49*, 101334. https://doi.org/10.1016/j.tsc.2023.101334

Arends, R. I. (2015). *Learning to Teach* (Tenth). New York: McGraw-Hill Education.

Astutik, S., & Prahani, B. K. (2018). The Practicality and Effectiveness of Collaborative Creativity Learning (CCL) Model by Using Phet Simulation to Increase Students' Scientific Creativity. *International Journal of Instruction*, *11*(4), 409–424. https://doi.org/10.12973/iji.2018.11426a

Bittermann, A., McNamara, D., Simonsmeier, B. A., & Schneider, M. (2023). The Landscape of Research on Prior Knowledge and Learning: a Bibliometric Analysis. *Educational Psychology Review*, *35*(2), 58. https://doi.org/10.1007/s10648-023-09775-9

Blackburn, J. J., & Robinson, J. S. (2016). Determining the Effects of Cognitive Style, Problem Complexity, and Hypothesis Generation on the Problem Solving Ability of School-Based Agricultural Education Students. *Journal of Agricultural Education*, *57*(2), 46–59. https://doi.org/10.5032/jae.2016.02046

Brand, C., Loibl, K., & Rummel, N. (2025). Prior knowledge activation as preparation prior to instruction: does the coverage of relevant prior knowledge affect learning? *Instructional Science*, *53*(6), 1633–1661. https://doi.org/10.1007/s11251-025-09727-6

Cerovac, M., & Keane, T. (2025). Early insights into Piaget's cognitive development model through the lens of the Technologies curriculum. *International Journal of Technology and Design Education*, *35*(1), 61–81. https://doi.org/10.1007/s10798-024-09906-5

Chettaoui, N., Atia, A., & Bouhlel, M. S. (2023). Student Performance Prediction with Eye-Gaze Data in

Embodied Educational Context. *Education and Information Technologies*, *28*(1), 833–855. https://doi.org/10.1007/s10639-022-11163-9

Chicco, D., Sichenze, A., & Jurman, G. (2025). A simple guide to the use of Student's t-test, Mann-Whitney U test, Chi-squared test, and Kruskal-Wallis test in biostatistics. *BioData Mining*, *18*(1), 56. https://doi.org/10.1186/s13040-025-00465-6

Çibukçiu, B. (2025). The impact of constructivist methods on students' mathematical problem-solving. *Discover Education*, *4*(1), 83. https://doi.org/10.1007/s44217-025-00475-w

Curtis, D. (2024). Welch's t test is more sensitive to real world violations of distributional assumptions than student's t test but logistic regression is more robust than either. *Statistical Papers*, *65*(6), 3981–3989. https://doi.org/10.1007/s00362-024-01531-7

Dabbagh, N. (2019). Effects of PBL on Critical Thinking Skills. In M. Moallem, W. Hung, & N. Dabbagh (Eds.), *The Wiley Handbook of Problem-Based Learning* (pp. 135–156). Hoboken: John Wiley & Sons, Inc.

Dolmans, D. H. J. M. (2019). How Theory and Design-Based Research Can Mature PBL Practice and Research. *Advances in Health Sciences Education*, *24*(5), 879–891. https://doi.org/10.1007/s10459-019-09940-2

Dong, A., Jong, M. S.-Y., & King, R. B. (2020). How Does Prior Knowledge Influence Learning Engagement? The Mediating Roles of Cognitive Load and Help-Seeking. *Frontiers in Psychology*, *11*(591203), 1–10. https://doi.org/10.3389/fpsyg.2020.591203

Eggen, P. D., Kauchak, D. P., & Garry, S. (2016). *Educational Psychology: Windows on Classrooms* (Tenth). Harlow: Pearson Education Limited.

Emden, M. (2021). Reintroducing "the" Scientific Method to Introduce Scientific Inquiry in Schools? *Science & Education*, *30*(5), 1037–1073. https://doi.org/10.1007/s11191-021-00235-w

Erawarni, D., & Yulianti, I. (2021). Analysis of Problem Formulation Skill of High School Students. *Physics Communication*, *5*(37), 53–59. https://journal.unnes.ac.id/nju/index.php/pc/article/view/36769/13162

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to Design and Evaluate Research in Education* (S. Kiefer (ed.); Eighth). New York: McGraw-hill New York.

Franestian, I. D., Suyanta, & Wiyono, A. (2020). Analysis Problem Solving Skills of Student in Junior High School. *Journal of Physics: Conference Series*, *1440*(1), 012089. https://doi.org/10.1088/1742-6596/1440/1/012089

Gayathri, B., Vedavyas, R., Sharanya, P., & Karthik, K. (2021). Effectiveness of Reflective Learning in Skill-Based Teaching Among Postgraduate Anesthesia Students: An Outcome-Based Study Using Video Annotation Tool. *Medical Journal Armed Forces India*, *77*, S202–S207. https://doi.org/10.1016/j.mjafi.2020.12.028

Ghofur, A., Jatmiko, B., & Sanjaya, I. G. M. (2023a). *HOPS Learning: Heuristic Oriented Problem-Solving Learning Model, Inovasi Pembelajaran Abad Ke-21 Dalam Melatihkan Keterampilan Pemecahan Masalah Siswa* (000559633). Kemenkumham RI. https://bit.ly/HKIBukuModelHOPS

Ghofur, A., Jatmiko, B., & Sanjaya, I. G. M. (2023b). Profile of High School Students' Problem-Solving Skills and the Application of Problem-Based Learning: a Preliminary Study. *Studies in Learning and Teaching*, *4*(3). https://doi.org/10.46627/silet.v4i3.317

Ghofur, A., Rahmana, D. I., Isbadrianingtyas, N., & Churiwiyah, U. (2025). *Beyond Traditional Pedagogy : The Effectiveness of Chemsite-PBL on Students ' Higher-Order Thinking Skills*. *10*, 67–76. https://doi.org/10.33752/ed-humanistics.v10i2.10539

Hake, R. R. (1999). Analyzing Change/Gain Scores. Dept. of Physics Indiana University. *Unpublished.[Online] URL: Http://Www. Physics. Indiana. Edu/~ Sdi/AnalyzingChange-Gain. Pdf.*

Halili, N., Rexhepi, A., Rexhepi, B., & Rexhepi, R. (2022). Global Challenges in The 21st Century. *Journal of Positive School Psychology*, *6*(4), 3438–3442. https://journalppw.com/index.php/jpsp/article/view/3883

Hariadi, B., Sunarto, M. J. D., Sagirani, T., Amelia, T., Lemantara, J., Prahani, B. K., & Jatmiko, B. (2021). Higher Order Thinking Skills for Improved Learning Outcomes Among Indonesian Students: A Blended Web Mobile Learning (BWML) Model. *International Journal of Interactive Mobile Technologies (IJIM)*, *15*(07), 4. https://doi.org/10.3991/ijim.v15i07.17909

Hasyim, F., Prastowo, T., & Jatmiko, B. (2024). Critical Thinking-Independent Learning: A Model of Learning to Improve Students' Critical Thinking Skills. *European Journal of Educational Research*, *13*(2), 747–762. https://doi.org/10.12973/eu-jer.13.2.747

Hmoud, M., Daher, W., & Ayyoub, A. (2025). From experience to engagement: a mixed methods exploration of learning environments using artificial intelligence and extended reality. *Frontiers in Education*, *Volume 10-2025*. https://doi.org/10.3389/feduc.2025.1617132

Kerr, J. (2016). Exploring Theoretical Frameworks of Problem Based Learning Through Aoki's Curriculum-as-Plan and Curriculum-as-Lived. In M. Filipenko & J.-A. Naslund (Eds.), *Problem-Based Learning in Teacher Education* (pp. 11–22). Switzerland: Springer International Publishing.

Khaparde, R. (2019). Experimental Problem Solving: A Plausible Approach for Conventional Laboratory Courses. *Journal of Physics: Conference Series*, *1286*(1), 012031. https://doi.org/10.1088/1742-6596/1286/1/012031

Komarudin, Marji, Sutadji, E., & Widiyanti. (2020). Increase the Problem Solving Ability Through Improved Prior Knowledge. *Journal of Physics: Conference Series*, *1700*(1), 012043. https://doi.org/10.1088/1742-6596/1700/1/012043

Kuang, X., Eysink, T. H. S., & de Jong, T. (2022). Effects of Providing Domain Information on Facilitating Hypothesis Generation In Inquiry Learning. *The Journal of Educational Research*, *115*(5), 285–297. https://doi.org/10.1080/00220671.2022.2124219

Kurniawan, E., & Sofyan, H. (2020). Application of Problem Based Learning Model to Improve Problem Solving Ability of Student of Xi Science Grade In Chemistry Lications and Applications. *Journal of Physics: Conference Series*, *1440*(1), 012014. https://doi.org/10.1088/1742-6596/1440/1/012014

Latha, S., & Christopher, P. (2020). Vuca in Engineering Education: Enhancement of Faculty Competency for Capacity Building. *Procedia Computer Science*, *172*, 741–747. https://doi.org/10.1016/j.procs.2020.05.106

Lehane, L. (2020). Experiential Learning-David A. Kolb. In B. Akpan & T. J. Kennedy (Eds.), *Science Education in Theory and Practice* (pp. 241–257). Switzerland: Springer.

Lestari, T., Arifin, Z., & Jatmiko, B. (2021). Virtual Classroom Critical Thinking as an Alternative Teaching Model to Improve Students' Critical Thinking Skills in Pandemic Coronavirus Disease Era. *European Journal of Educational Research*, *10*(4), 2003–2015. https://doi.org/10.12973/eu-jer.10.4.2003

Levin, I., & Mamlok, D. (2021). Culture and Society in the Digital Age. *Information*, *12*(2), 68. https://doi.org/10.3390/info12020068

Li, D. (2022). Psychological Emotion and Behavior Analysis in Music Teaching Based on the Attention, Relevance, Confidence, and Satisfaction Motivation Model. *Frontiers in Psychology*, *Volume 13-2022*. https://doi.org/10.3389/fpsyg.2022.917476

Lonergan, R., Cumming, T. M., & O'Neill, S. C. (2022). Exploring the Efficacy of Problem-Based Learning in Diverse Secondary School Classrooms: Characteristics and Goals Of Problem-Based Learning. *International Journal of Educational Research*, *112*, 101945. https://doi.org/10.1016/j.ijer.2022.101945

Lusiana, R., & Andari, T. (2020). Brain Based Learning to Improve Students' Higher Order Thinking Skills. *Journal of Physics: Conference Series*, *1613*(1). https://doi.org/10.1088/1742-6596/1613/1/012004

Mabley, S., Ventura-Medina, E., & Anderson, A. (2020). 'I'm Lost'- A Qualitative Analysis of Student Teams'' Strategies During Their First Experience in Problem-Based Learning.'. *European Journal of Engineering Education*, *45*(3), 329–348. https://doi.org/10.1080/03043797.2019.1646709

Magaji, A. (2021). Promoting Problem-Solving Skills among Secondary Science Students through Problem Based Learning. *International Journal of Instruction*, *14*(4), 549–566. https://doi.org/10.29333/iji.2021.14432a

Mamun, M. A. Al, & Lawrie, G. (2024). Cognitive presence in learner–content interaction process: The role of scaffolding in online self-regulated learning environments. *Journal of Computers in Education*, *11*(3), 791–821. https://doi.org/10.1007/s40692-023-00279-7

Marcinauskas, L., Iljinas, A., Čyvienė, J., & Stankus, V. (2024). Problem-Based Learning versus Traditional Learning in Physics Education for Engineering Program Students. *Education Sciences*, *14*(2), 154. https://doi.org/10.3390/educsci14020154

Martaningsih, S. T., Maryani, I., Prasetya, D. S., Prwanti, S., Sayekti, I. C., Aziz, N. A. A., & Siwayanan, P. (2022). Stem Problem-Based Learning Module: A Solution to Overcome Elementary Students' Poor Problem-Solving Skills. *Pegem Journal of Education and Instruction*, *12*(4), 340–348. https://doi.org/10.47750/pegegog.12.04.35

Martín-Lucas, J., & Dujo, Á. G. del. (2023). Knowledge-building in an environment mediated by digital technology: A case study in higher education. *Education and Information Technologies*, *28*(3), 3267–3287. https://doi.org/10.1007/s10639-022-11304-0

Mashluhah, M. I., Prahani, B. K., Suryanti, S., & Jatmiko, B. (2019). The Effectiveness of ORDEP2E Learning Model to Train the Natural Science Problem-Solving Skills of Primary School Students. *Journal of Physics: Conference Series*, *1157*(2), 022011. https://doi.org/10.1088/1742-6596/1157/2/022011

Mei, Q., Chan, N. N., Gill, R. S., Subramaniam, N., Motevalli, S., & Ang, C.-S. (2025). Impact of attention, relevance, confidence, satisfaction (ARCS) model on teaching effectiveness in higher education: a systematic review. *Discover Education*, *4*(1), 252. https://doi.org/10.1007/s44217-025-00674-5

Molino, M., Cortese, C. G., & Ghislieri, C. (2020). The Promotion of Technology Acceptance and Work Engagement in Industry 4.0: From Personal Resources to Information and Training. *International Journal of Environmental Research and Public Health*, *17*(7), 2438. https://doi.org/10.3390/ijerph17072438

Morris, T. H. (2020). Experiential learning–a systematic review and revision of Kolb's model. *Interactive Learning Environments*, *28*(8), 1064–1077. https://doi.org/10.1080/10494820.2019.1570279

Muhammed, M. J., Hasan, S. A., & Huseyn, W. M. (2022). The Effect of the Strategy of Activating Prior Knowledge on the Acquisition of Syntactic Concepts among Fourth Preparatory Grade Students and the Development of their Systemic Thinking. *International Journal of Early Childhood Special Education*, *14*(1), 738–747. https://doi.org/10.9756/INT-JECSE/V14I1.221087

Nagpal, M., Lin, T.-J., Kraatz, E., Kim, S., Ha, S. Y., & Glassman, M. (2025). Reciprocal interactions between teachers' instructional moves and students' social reasoning during collaborative small group discussions. *Instructional Science*, *53*(4), 867–899. https://doi.org/10.1007/s11251-025-09718-7

Naji, K. K., Ebead, U., Al-Ali, A. K., & Du, X. (2020). Comparing Models of Problem and Project-Based Learning (PBL) Courses and Student Engagement in Civil Engineering in Qatar. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(8), em1867. https://doi.org/10.29333/ejmste/8291

OECD. (2023). *PISA 2022 Results The State of Learning and Equity in Education Publication Volume I*. Paris: OECD. https://doi.org/10.1787/53f23881-en

Pallant, J. (2020). *Survival Manual A Step by Step Guide to Data Analysis Using IBM SPSS* (7th Editio). New York: Routledge.

Pozas, M., Löffler, P., Schnotz, W., & Kauertz, A. (2020). The Effects of Context-based Problem-solving Tasks on Students' Interest and Metacognitive Experiences. *Open Education Studies*, *2*(1), 112–125. https://doi.org/10.1515/edu-2020-0118

Putri, M. D., Rusdiana, D., & Rochintaniawati, D. (2019). Students' Conceptual Understanding in Modified Flipped Classroom Approach: An Experimental Study in Junior High School Science Learning. *Journal of Physics: Conference Series*, *1157*(2), 0–7. https://doi.org/10.1088/1742-6596/1157/2/022046

Rios, J. A., Ling, G., Pugh, R., Becker, D., & Bacall, A. (2020). Identifying Critical 21st-Century Skills for Workplace Success: A Content Analysis of Job Advertisements. *Educational Researcher*, *49*(2), 80–89. https://doi.org/10.3102/0013189X19890600

Riyadi, R., Syarifah, T. J., & Nikmaturrohmah, P. (2021). Profile of Students' Problem-Solving Skills Viewed from Polya's Four-Steps Approach and Elementary School Students. *European Journal of Educational Research*, *volume-10*-(volume-10-issue-4-october-2021), 1625–1638. https://doi.org/10.12973/eu-jer.10.4.1625

Robey, A., Castillo, C., Ha, J., Kerlow, M., Tesfa, N., & Dougherty, M. (2022). Generalizing the effect of type of metacognitive judgment on restudy decisions. *Metacognition and Learning*, *17*(1), 73–85. https://doi.org/10.1007/s11409-021-09274-8

Santrock, J. W. (2018). *Educational psychology* (Sixth). New York: McGraw-Hill Education.

Schneider, M., & Simonsmeier, B. A. (2025). How does prior knowledge affect learning? A review of 16 mechanisms and a framework for future research. *Learning and Individual Differences*, *122*, 102744. https://doi.org/https://doi.org/10.1016/j.lindif.2025.102744

Scott, K. S. (2017). An Integrative Framework for Problem-Based Learning and Action Learning: Promoting Evidence-Based Design and Evaluation in Leadership Development. *Human Resource Development Review*, *16*(1), 3–34. https://doi.org/10.1177/1534484317693090

Seow, P.-S., Pan, G., & Koh, G. (2019). Examining an Experiential Learning Approach to Prepare Students for The Volatile, Uncertain, Complex and Ambiguous (VUCA) Work Environment. *The International Journal of Management Education*, *17*(1), 62–76. https://doi.org/10.1016/j.ijme.2018.12.001

Shishigu, A., Hailu, A., & Anibo, Z. (2018). Problem-Based Learning and Conceptual Understanding of College Female Students in Physics. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(1). https://doi.org/10.12973/ejmste/78035

Simonsmeier, B. A., Flaig, M., Deiglmayr, A., Schalk, L., & Schneider, M. (2022). Domain-Specific Prior Knowledge and Learning: A Meta-Analysis. *Educational Psychologist*, *57*(1), 31–54. https://doi.org/10.1080/00461520.2021.1939700

Siswanto, J., Susantini, E., & Jatmiko, B. (2018). Practicality and Effectiveness of The IBMR Teaching Model to Improve Physics Problem Solving Skills. *Journal of Baltic Science Education*, *17*(3), 381–394. https://doi.org/10.33225/jbse/18.17.381

Slavin, R. E. (2018). *Educational Psychology: Theory and Practice* (Twelfth). New York: Pearson Education, Inc.

Solomon, Y. (2020). Comparison Between Problem-Based Learning and Lecture-Based Learning: Effect on Nursing Students' Immediate Knowledge Retention. *Advances in Medical Education and Practice*, *Volume 11*, 947–952. https://doi.org/10.2147/AMEP.S269207

Suprapto, W., Ghofur, A., Rahman, D. I., Churiwiyah, U., & Kariadi, D. (2025). Improving Students ' Tolerance Through The VCT Learning Model : A Quasi-Experimental Study. *Journal of Educational Review and Research*, *8*(2), 185–192. https://doi.org/10.26737/jerr.v8i2.8591

Susilawati, Ramalis, T. R., Kaniawati, I., & Rusdiana, D. (2021). Connections Between Prior Knowledge and Collaborative Skill on Discussion Group About Solar System Related to Descriptive Scientific Reasoning. *Journal of Physics: Conference Series*, *1918*(5), 052052. https://doi.org/10.1088/1742-6596/1918/5/052052

Syarifudin, S., Purwanto, P., Irawan, E. B., Sulandra, I. M., & Fikriyah, U. (2019). Student Verbal Interaction in Geometry Problem-Solving Through Cognitive Activities. *International Journal of Instruction*, *12*(3), 167–182. https://doi.org/10.29333/iji.2019.12311a

Tawfik, A. A., Hung, W., & Giabbanelli, P. J. (2020). Comparing How Different Inquiry-based Approaches Impact Learning Outcomes. *Interdisciplinary Journal of Problem-Based Learning*, *14*(1). https://doi.org/10.14434/ijpbl.v14i1.28624

Valdez, J., & Bungihan, M. (2019). Problem-Based Learning Approach Enhances the Problem Solving Skills in Chemistry of High School Students. *Journal of Technology and Science Education*, *9*(3), 282. https://doi.org/10.3926/jotse.631

Wahyuni, S., Erman, E., Sudikan, S., & Jatmiko, B. (2020). Edmodo-Based Interactive Teaching Materials as an Alternative Media for Science Learning to Improve Critical Thinking Skills of Junior High School Students. *International Journal of Interactive Mobile Technologies (IJIM)*, *14*(09), 166. https://doi.org/10.3991/ijim.v14i09.13041

Wang, Y.-P. (2021). Effects of Online Problem-Solving Instruction and Identification Attitude Toward Instructional Strategies on Students' Creativity. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.771128

Wong, L.-H., & Looi, C.-K. (2019). The Conceptual Niche of Seamless Learning: An Invitation to Dialogue. In C.-K. Looi, L.-H. Wong, C. Glahn, & S. Cai (Eds.), *Seamless Learning: Perspectives, Challenges and Opportunities*. Singapore: Springer Nature Singapore Pte Ltd.

Woolfolk, A. (2021). *Educational Psychology, Fourteenth Edition* (Fourteenth). Harlow: Pearson Education Limited.

World Economic Forum. (2023). *Future of Jobs Report 2023, Insight Report May 2023*. https://www.weforum.org/reports/the-future-of-jobs-report-2023/

Yoon, J., Hur, E. J., & Kim, M. (2020). An Analysis of the Factors on the Problem-Solving Competencies of Engineering Employees in Korea. *Sustainability*, *12*(4), 1677. https://doi.org/10.3390/su12041677

Yunus, M., Setyosari, P., Utaya, S., & Kuswandi, D. (2021). The Influence of Online Project Collaborative Learning and Achievement Motivation on Problem-Solving Ability. *European Journal of Educational Research*, *10*(2), 813–823. https://doi.org/10.12973/eu-jer.10.2.813

Zheng, Q.-M., Li, Y.-Y., Yin, Q., Zhang, N., Wang, Y.-P., Li, G.-X., & Sun, Z.-G. (2023). The Effectiveness of Problem-Based Learning Compared with Lecture-Based Learning in Surgical Education: A Systematic Review and Meta-Analysis. *BMC Medical Education*, *23*(1), 546. https://doi.org/10.1186/s12909-023-04531-7