JPPIPA 10(8) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Problem Solving Learning in Science Education: A Systematic Literature Review

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Received: August 19, 2023
Revised: May 22, 2024
Accepted: August 25, 2024
Published: August 31, 2024

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DOI: 10.29303/jppipa.v10i8.5033

Abstract: This study aims to describe the application of problem solving in the learning process and describes the technique of forming groups that are carried out in learning. This study uses the Systematic Literature Review method, which focuses on reviewing and analyzing broadly and thoroughly some of the literature that is relevant to the research topic. The stages carried out in this research are clarification and approach; search, filter, and select; analysis and interpretation; draft articles; and dissemination. Literature data used as the main source in this study were 15 articles from Scopus-indexed Springer within a period of 6 years (2018-2023). The articles analyzed examined problem solving skills ranging from junior high school to university. The results showed problem solving research was carried out individually and in groups, and most research was done through groups. The technique of forming groups is carried out by paying attention to the background, results of initial ability tests in individual rounds, pretest, and educational strata. The steps taken in learning problem solving are: orientation of students to problems; group formation; carrying out investigative activities to solve problems; discussing and reviewing problem solving strategies in groups; making presentations; and the teacher providing feedback.

Keywords: Problem solving; Science; Systematical literature review

Introduction

The development of problem-solving skills is now one of the goals of Science Education in the 21st Century (Greiff et al., 2013; Scherer et al., 2012; van Merriënboer, 2013). There are at least two reasons why problem solving is important (Niss, 2018). First, problem solvers can facilitate students in learning physics concepts. Second, the development of problem solving competence is the goal of Physics Education itself. This second opinion reflects that science must reflect the nature of problem solving which is an important part of scientific inquiry. Science is also an aid to students in developing the skills needed to solve real-world problems.

Problem solving is a cognitive process where students will feel the difference between the current situation and the desired goal, then change the given situation into a goal. To deal with difficulties, students' problem solving skills refer to the capacity to engage in cognitive processing to understand and adjust to problem situations where the solution is not immediately visible (OECD, 2010). Problem solving allows students to learn by working on problems through processes such as observing, processing information, interpreting, planning, formulating conclusions, and reflecting (OECD, 2017). In science education, when students collaborate with others to understand each other by sharing ideas and reasoning

How to Cite:
Susilawati, E., Hamidah, I., Rustaman, N., & Liliawati, W. (2024). Problem Solving Learning in Science Education: A Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 548–558. https://doi.org/10.29303/jppipa.v10i8.5033

with others to understand the process they use to solve scientific questions and applied problems (Hogan, 1999).

Problem solving activities in learning have been done in various ways. Hesse et al. (2015) have considered incorporating collaboration in problem solving. Problem solving is carried out as a joint activity in small groups in carrying out a number of steps to solve the intended problem. In collaborative problem solving, joint construction of ideas and problem solving, the contribution of individual knowledge and skills to the group, and processes in different parts influencing one another are considered to be the most important factors.

Research on problem solving has been widely carried out starting from problem solving activities examined as treatment measures as well as measured variables. It is usually carried out by means of experimental research, mixed methods, or sometimes a qualitative analysis of the problem solving curriculum is carried out. Research on problem-based learning in education is usually carried out looking at the influence (Kusumawardani et al., 2024; Meidiana et al., 2024; Prihatin, 2024; Rinaningsih et al., 2024), the development of learning tools (Handayani et al., 2024; Novitha et al., 2023; Sapira et al., 2024; Saputra et al., 2024).

However, not much research on problem solving has mapped out how learning is done. Among them is how problem solving is done whether through groups or individuals. If done with a group, how is the grouping technique in problem solving learning that has been done by previous researchers.

Based on the background, it is therefore important to map out how learning about problem solving has been done so far. The questions in this study are: How is the application of problem solving in research so far? And what is the group formation technique that has been carried out?

Method

This study used a systematical literature review (SLR). This literature review aims to find a clear, coherent and accountable method. Systematic Literature Review was conducted to answer research questions (Gough et al., 2017).

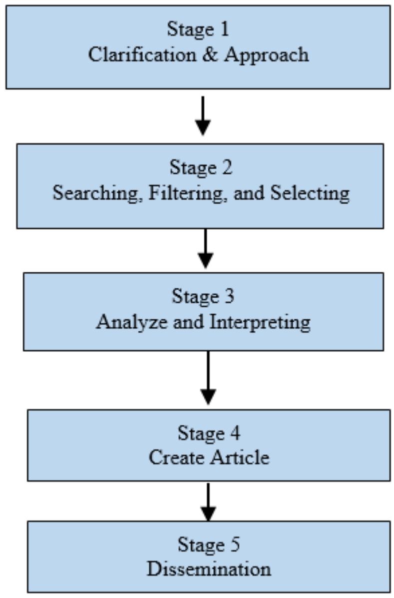

Figure 1. Research steps

The research uses secondary data from articles related to problem solving in learning the natural sciences education, whether Physics, Chemistry, or Biology. Researchers selected 15 reputable international articles from 2018 to 2023. A summary of the selected journals for review can be seen in Table 1.

Table 1. List of Journal Articles Analyzed

Journal Name	Amount	Indexed By
Cognitive, Affective, & Behavioral Neuroscience	1	Scopus
Disciplinary and Interdisciplinary Science Education Research	1	Scopus
Instructional Science	1	Scopus
International Journal of Science and Mathematics Education	2	Scopus
Journal of Science Education and Technology	2	Scopus
Physical Review Physics Education Research	1	Scopus
Research and Practice in Technology Enhanced Learning	1	Scopus
Research in Science Education	3	Scopus
Science & Education	2	Scopus
Technology, Knowledge and Learning	1	Scopus

The stages of the procedure used in this study were adopted from the research of Winarno et al. (2020). The first step is clarification and approach. The clarification and approach stages are steps to explore the rationale for reviewing articles related to problem solving in science education, then determining research questions, article criteria, and forming a research framework.

The second step is searching, filtering, and selecting. At the stage of searching, filtering, and selecting researchers looking for articles that explain problem solving in science education. Journal search is done through the Springer database. Then the researcher screened and validated the articles to ensure that the selected articles met criteria. The author chooses to use articles from Scopus indexed international journals and selects the 15 most related articles.

The third step, analyze and interpret. In the analyzing and interpreting stage, the writer analyzes the representation of the research characteristics. The results of data analysis are then described using tables. After that, the writer discusses and interprets the data that has been obtained. The fourth step is create a draft article. The results of data analysis are made into draft articles. After that, the author adjusts the draft of the article to the intended journal template. And the final step is dissemination. In this stage, the articles that have been made are then published in journals.

Result and Discussion

In this study, research representation according to characteristics generally includes the type of publication, year of publication, research approach and level of education. The research results analyzed have been published in Scopus indexed journals. Research representation according to publication year can be seen in Table 2.

Table 2. Research Representation by Year

Year	F
2018	2
2019	2
2020	7
2021	1
2022	2
2023	1
Amount	15

Table 2 explains that the selected articles related to problem solving in Science Education from 2018 to 2023. The articles selected for review consisted of 2 articles in 2018, 2 articles in 2019, 7 articles in 2020, 1 article in 2021, 2 articles in 2022, and 1 article in 2023. This shows that the articles being reviewed are up to date articles, so it is hoped that the research results can be used by stakeholders related to Science Education. The research approach used in this study includes quantitative, qualitative, and mixed methods.

Based on Table 3, it can be seen that the most widely used research approach is quantitative with 10 articles (67%), while the mixed method with 5 articles (33%). Based on these data it was concluded that the research approach used related to problem solving in science education learning was quantitative research.

Table 3. Research Representation Based on Research Approach

Research approach	F	Percentage (%)
Quantitative	10	66.67
Qualitative	-	-
Mixed method	5	33.33
Amount		100

In addition to analyzing based on research methods, it is also analyzed based on research subjects based on educational level. The level of education covered starts from junior high school, high school, to the university level. Research representation based on education level can be seen in Figure 2.

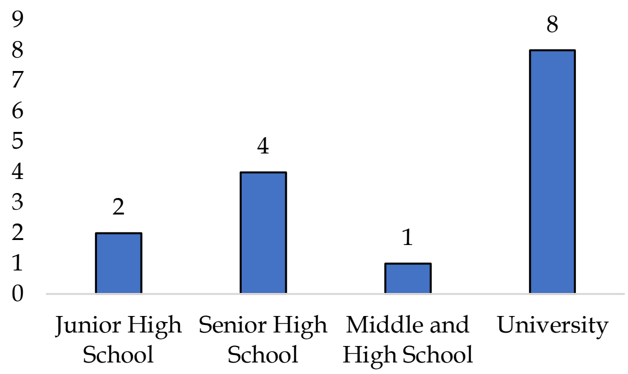

Figure 2. Research representation based on education level

Figure 2 shows the participants in the study of problem solving in science education. They consist of students and students. Most studies used participants from students with 8 articles (53.3%), high school students 4 articles (26.7%), junior high school students 2 articles (13.3%) and junior high and high school students 1 article (6.67%) .

In this study, learning with the theme of problem solving was divided based on the author, the title of the article, and the results of the article. The results of this study can be seen in Table 4.

Table 4. Research Results with the Theme of Problem Solving

Year	Writer	Title	Results
2018	Cristofori et al.	The effects of expected reward on Creative Problem Solving	Participants solved more problems through insight following high subliminal rewards when compared to low subliminal rewards, and compared to high supraliminal rewards, with no corresponding effect on analytic completion. Striatal dopamine (DA) is thought to influence motivation, reinforce behavior, and

Year	Writer	Title	Results
			facilate cognition. We speculate that subliminal reward activates the striatal DA system, increasing the kind of automatic integration process that leads to more creative strategies for problem solving, without increasing attention selectivity, which can hinder insight.
	Wen et al.	The learning analytics of model-based learning is facilitated by a problem solving simulation game	It was found that most of the students were able to build good quantitative models to solve problems. Problem-solving simulation games have the potential to help students reflectively play with science problems and build workable models to solve them. Furthermore, LSA analysis also identified reasons why other students failed to construct scientific models to solve problems. When students rely on intuitive knowledge in reference materials and do not link that knowledge to their modeling actions, they can only build fragile and unstable models and are unable to apply models appropriately in other contexts.
2019	Dokme & Unlu	The challenge of quantum physics problems with self-metacognitive questioning	The results show that self-metacognitive questions for non-routine quantum physics problems create a statistical effect that supports the attitude of the experimental group students towards the quantum physics course. Changes in the positive attitude of students in the control group resulted from cognitive and behavioral components while changes in positive attitudes of students in the experimental group were caused by cognitive, behavioral and affective components. A significant difference in favor of the experimental group was seen in the affective attitude component (Factor 2; having a qualification from the course). These results lead to the important conclusion that self-metacognitive training positively influences the affective component of attitudes
	Chen et al.	Direction of collaborative problem solving based on STEM learning by learning analytics approach	Significant positive correlations were found for learning behavior using markers with learning performance and CPS awareness in group discussions, whereas significant negative correlations were found for some factors of STEM learning strategies and learning behavior in pre- learning with some factors of CPS awareness. The results imply the importance of an efficient approach to using learning strategies and functional tools in STEM education.
2020	LiChen et al.	Exploring factors that influence collaborative problem solving awareness in science education	There is a significant positive correlation between CPS awareness and certain learning motivation factors and learning behavior factors
	Nam Ju Kim et al.	Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving	The results reveal that various students may use scaffolding in different ways based on different goals and previous experiences.
	Hartono Bancong; Jinwoong Song	Exploring how students construct collaborative thought experiments during physics problem-solving activities	TE can be built in a collaborative way although TE is a process of personal and tacit experimentation of scientists in constructing scientific theories. The activity of visualizing an imaginary world where experiments are designed and generated by one or more individuals in their own mind laboratories and then sharing them with group members to run and evaluate together as a collective effort to reach a conclusion is defined as collaborative TE. There are five steps in conducting collaborative TE: visualizing an imaginary world, conducting experiments, describing results, sharing and evaluating experiments, and drawing conclusions.
	Nimet Akben	Effects of the problem-posing approach on students' problem solving skills and metacognitive awareness in science education	The results showed that structured, semi- structured, and independent problem posing activities improved students' problem solving skills and metacognitive awareness.
	Cigdem Uz-Bilgin et al.	Exploring how role and background influencethrough analysis of spatial dialogue in	The player's role and familiarity with the game topic all have an impact on the spatial context information that is shared during game play. Game play experience, familiarity with VR technology,

Year	Writer	Title	Results
		collaborative problem-solving games	spatial abilities including mental rotation abilities, spatial reasoning, or object location memory can influence learning performance.
	Park	Students' problem-solving strategies in qualitative physics questions in assimilation-based formative assessment	The findings show that students still use equations to answer qualitative questions, but the way of using equations is different between students. This study found that when students can relate variables to physical processes and interpret the relationships between variables in an equation, the equation is used as a tool of conceptual explanation or understanding, not just a computational tool.
	Robinson et al.	Using open-source videos to flip a first-year college physics class	There was no statistically significant difference in concept inventory performance before and after the course was reversed. Students scored higher in related laboratory courses and in subsequent quantitative reasoning courses after the courses were reversed. There were no statistically significant differences between scores in subsequent physics courses or by sex after the courses were reversed.
	FanYu Yeh et al.	A study of environmental literacy, scientific performance, and environmental problem solving	The results showed that students with higher scores in environmental scientific achievement scored higher in environmental problem solving (EPS) as well. However, students with higher scores in environmental literacy were able to propose better EPS strategies, analyze EPS solutions keenly, and present multiple plans.
2022	Jiwon Lee et al.	Effect of group type on group performance in peer-collaborated two-round physics problem solving	The number of correct answers in the individual round is important for group performance, both individually and as a group. Then the majority of right-wrong answers in individual rounds contributed to group performance. And variation in answers on individual rounds is important for group performance.
	Wancham et al.	Effects of feedback types and opportunities to change answers on achievement and ability to solvephysics problems	The result of this study: participants were given static feedback with clues and those who were given reducing feedback with clues had attainment of and much higher ability to solve physics problems than the participants were given knowledge of feedback responses at a significance level of 0.05. Allowed participants changing answers has far more achievements and physics problem solving abilities higher than participants who were not allowed to change their answers at a significance level of 0.05. Beside that, there is no interaction between the type of feedback and the opportunity to change answers to achievement and ability to solve physics problems at a significance level of 0.05. Therefore, instructor should provide static feedback with prompts or reduce feedback with prompts instead of providing knowledge about response feedback to students. Additionally, participants students must be given the opportunity to change answers in order to improve achievement and abilities solve physics problems in a formative assessment environment. However, the instructor must provide computer-based feedback because it is efficient to provide standardized feedback right away various students.
2023	Timothy et al.	Fostering preservice teachers' diagnostic competence in identifying students' misconceptions in physics	The findings show that problem-solving strategies are better than example-based strategies in increasing conceptual diagnostic knowledge. The results showed that the problem-solving strategy increased teacher candidates' conceptual diagnostic knowledge significantly more than the example-based strategy. The results also indicated that the problem-solving strategy increased preservice teachers' conceptual diagnostic knowledge significantly more than the control condition. The example-based strategy did not improve the prospective teacher's conceptual knowledge significantly more than the control condition.

Based on the results of the research analysis that has been carried out previously, it was found that problem-solving skills can be improved through enhanced games (Wen et al., 2018), videos (Robinson et al., 2020). Apart from the media, other things that can improve problem-solving skills are questions of self-metacognition (Dokme et al., 2019), self-motivation (Chen et al., 2020), use of scaffolding (Kim et al., 2022), providing feedback (Wancham et al., 2022), giving rewards (Cristofori et al., 2018), and the type of group formation (Bancong et al., 2020). In addition, research has been carried out on assessment assessments in problem solving strategies through qualitative questions (Park, 2020). Problem solving can be done if participants have good knowledge (Yeh et al., 2022). Problem selection can also be an option in problem solving research. Problem solving that is carried out in a structured, semi-structured, and free manner can also improve problem solving skills (Akben, 2020). One learning model that supports increasing problem solving skills is the STEM model with an analytical approach (Chen et al., 2019). Through learning problem solving it is also able to improve the diagnostic abilities of prospective teachers to identify misconceptions about physics in students (Timothy et al., 2023).

Problem solving learning was not only done in groups, but also done individually. Representation of group and individual problem solving learning can be seen in Table 5.

Table 5. Learning Problem Solving

Learning Method	F
Group	9
Individual	6

Based on the results of the analysis, it appears that research with the theme of problem solving is mostly done through groups, there are 9 articles and individuals, there are 4 articles. Based on the 6 articles, we analyzed the method of learning in groups as shown in Table 6.

Table 6. How to Form Groups in Problem Solving Learning

Title	How to Form a Group
Exploring factors that influence collaborative problem solving awareness in science education	Not paying attention to how to form a group.
Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving	Based on pretest scores by dividing evenly into four groups.
Exploring how students construct collaborative thought experiments during physics problem-solving activities	Distribution based on educational strata (S1 with S1, S1 with S2, and S2 with S2)
Effects of the problem-posing approach on students'problem solving skills and metacognitive awareness in science education	Not paying attention to how to form a group.
Effect of group type on group performance in peer-collaborated two-round physics problem solving	Based on the number of correct answers in individual rounds, groups are formed based on the number of correct answers. Group A is a member of the group that has all the correct answers, group B is the correct answer more than half and group C is the correct answer less than half in the individual round, group D has no correct answers
Exploring how role and background influence through analysis of spatial dialogue in collaborativeproblem-solving games	Based on participants' background knowledge, their level of relationship, participant's gender, experience, prior knowledge, prior demographic information.
Fostering preservice teachers' diagnostic competencein identifying students' misconceptions in physics	In groups but there is no explanation of how to form groups
Using open-source videos to flip a first-year college physics class	In groups but there is no explanation of how to form groups
Direction of Collaborative Problem Solving Based on STEM learning by learning analytics approach	In groups but there is no explanation of how to form groups

Based on the results of the analysis of group formation techniques in each study, group formation techniques can be done in various ways. Research conducted by Kim et al. (2022), divided the groups based on the initial scores (pretest) of the participants. Meanwhile Bancong et al. (2020), divided the groups by considering the level of education, namely from S1 and S2. Within this group, the researcher divided S1 with S1, S1 with S2, and S2 with S2. While research Lee et al. (2022), divided the groups by paying attention to the correct answers in the new individual round bringing them to the group round. Group formation in a different way is done by Uz-Bilgin et al. (2020) who divided the groups based on the background of the participants. Participants' backgrounds considered were the relationship between participants, gender, experience, prior knowledge, prior demographic information. Meanwhile, in two other studies that conducted problem solving research in groups, they did not specifically explain how to divide groups. Through this study, information was obtained that group formation can be done in various ways, namely: the background of the participants, the level of education, and the initial abilities of the participants. This is considered important in supporting the participants' problem-solving abilities. Collaboration in problem solving is expected to be integrated.

The steps in providing problem solving learning carried out by researchers are different. Description of the steps taken by researchers for problem solving is shown in Table 7.

Table 7. Description of the Steps Taken by Researchers for Problem Solving

Year	Writer	Title	Learning Steps
2018	Irene Cristofori et al.	The effects of expected reward on creative problem solving	The first step is to orient participants to the task. Next, participants solve problems through insight or t an analytical process. The final step is to give prizes to participants who solve the problem.
	Wen et al.	The learning analytics of model-based learning is facilitated by a problem solving simulation game	Students begin by visiting game pages to read the problem descriptions. They then engage with simulation games and create their own models. After developing their models, they test them to solve the problems. Following this, students write or revise the reports they produce based on their findings. The reports are then reviewed for accuracy and completeness. Throughout the learning process, students diligently record all important information.
2019	Dokme & Unlu	The challenge of quantum physics problems with self- metacognitive questioning	The process begins with an introduction to the material to be presented. This is followed by instruction on the relevant theory. Next, non-routine problems related to the taught theory are presented. Students then work on solving these problems. Finally, feedback is provided on their problem-solving efforts.
	Chen et al.	Direction of collaborative problem solving based on STEM learning by learning analytics approach	In the pre-learning stage, utilize marking and annotation tools available on the bookroll system. During the problem statement stage, engage in discussions regarding the issues identified and marked in the bookroll system during the pre-learning stage. In the presentations stage, present all the identified problems and solicit feedback from other groups. Finally, in the conclusion stage, summarize the learning activities conducted throughout the process.
2020	LiChen et al.	Exploring factors that influence collaborative problem solving awareness in science education	Begin with the introduction and problem statement. After tahat proceed with individual thinking to develop initial ideas. Then engage in group discussions to further explore and refine these ideas; develop a solution based on the collaborative discussions. Present the solution to the larger group or audience. The last, draw conclusions from the entire process.
	Nam Ju Kim et al.	Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving	Begin by developing a topic, followed by creating a search strategy. Next, identify potential sources relevant to the topic. Proceed to find and evaluate these sources of information. And last is recognize how to effectively use the gathered information.
	HartonoBancong; Jinwoong Song	Exploring how students construct collaborative thought experiments during physics problem- solving activities	Visualize an imaginary world where words and body movements serve as indicators. Next, students conduct experiments in their minds. Then, students discuss with each other to describe the results of their thought experiments (TE). Following this, they share and evaluate their TE results, describing them to all group members. Finally, draw a conclusion. This step involves agreeing and making decisions after considering the information

Year	Writer	Title	Learning Steps
			through negotiations, allowing students to gain new knowledge and apply it in the real world.
	Nimet Akben	Effects of the problem-posing approach on students' problem solving skills and metacognitive awareness in science education	First, identify the problem to be addressed. Then, proceed to develop solutions to the problem. Following this, carry out investigative activities to explore and address the problem effectively.
	Cigdem Uz-Bilginet al.	Exploring how role and background influencethrough analysis of spatial dialogue in collaborative problem-solving games	The first step taken is to orientate towards learning activities. Next, distribute roles between students. In this research, the learning stages were directly outlined through the game instructions.
	Park	Students' problem-solving strategies in qualitative physics questions in assimilation-based formative assessment	The first step is to give students a certain situation, then students are asked to predict what will happen next. After students answer the questions, the simulation is then run and students are asked to explain the results. Next, students complete the implementation, then conduct interviews with students who have successfully implemented it.
	Robinson et al.	Using open-source videos to flip a first-year college physics class	Students are first asked to watch the learning video before the lecture begins. Subsequently, they complete the questions at the end of each chapter, typically in a short 20-minute video format. During regular classes, students receive a mini-lecture, lasting 10 to 20 minutes, to review the material, address questions, and prepare problems. These problems are contextual, reflecting real-world scenarios. Afterward, students are divided into groups to solve these problems. They then discuss and review the solutions to the problems in a classical format. Students are required to submit their group solutions for assessment. Finally, the teacher provides feedback and showcases the best problem-solving approaches before moving on to the next topic.
2021	FanYu Yeh et al.	A study of environmental literacy, scientific performance, and environmental problem Solving	Understanding environmental issues is the first step, followed by analyzing potential solutions to these problems. Afterward, assess these solutions to determine their effectiveness. Finally, propose suitable solutions that can effectively address the identified problems.
2022	Jiwon Lee et al.	Effect of group type on group performance in peer-collaborated two-round physics problem solving	In the individual rounds, students submit their own answers. Subsequently, they form groups and discuss the questions with their group members. They then provide feedback to each other within the group. Following this, the groups present their answers to the class, and the class provides responses to these group answers.
	Wancham et al.	Effects of feedback types and opportunities to change answers on achievement and ability to solve physics problems	The first stage involves analyzing the physics problem and examining the given and sought quantities, then formulating equations to solve the problem. The second stage is the mathematical stage, where students are asked to solve the equations in two steps to obtain the answer. The final stage is the analysis of the solution, which involves checking the dimensions or units of the answer, its physical meaning, and the possible values.
2023	Timothy et al.	Fostering preservice teachers' diagnostic competence in identifying students' misconceptions in physics	The first step is facilitating students in solving problems is essential; therefore, using examples of work to demonstrate and explain the problem-solving process is crucial. Next, observing experts or peers who are more skilled in problem-solving can provide valuable insights. Finally, gradually reducing the number of examples allows for more autonomy, giving students the opportunity to tackle problems independently.

The steps in carrying out learning about problem solving are carried out in various ways. Learning is also carried out in various ways, starting with using software and video as media, differentiating the structure of the problem, or the type of group. Of these various ways, in general the steps taken in learning about problem solving are: orientation of students to problems; then formation of groups; carry out investigative activities to solve problems; discuss and review problem solving strategies in groups; make presentations; and the teacher provides feedback.

Based on Tables 7 and 8, it is clear that apart from paying attention to learning steps, researchers also need to pay attention to how groups are formed. This aims to ensure that the contributions of all participants are guaranteed. Through collaboration, students are facilitated to participate with each other in solving group problems (Wijaya et al., 2024). Apart from that, collaboration in group learning helps students to share ideas, take responsibility, work effectively to solve problems and achieve common goals (Hadiwangsa et al., 2024). Therefore, difficulties in understanding abstract and complex concepts can be overcome (Dewi et al., 2024).

Conclusion

Based on the results of the analysis and discussion above, it can be concluded that problem solving learning is done in groups and individually. Group formation techniques are carried out by: taking into account background (closeness between participants, gender, relationships, and geographic demographics), results of initial ability tests in individual rounds, pretest results, and educational strata. The steps for learning problem solving in general are orientation of students to problems; formation of groups; carry out investigative activities to solve problems; discuss and review problem solving strategies in groups; make presentations; and the teacher provides feedback.

Acknowledgments
The researcher would like to thank the Education Funding Center (PUSLAPDIK) of The Ministery of Education and Cuture for giving me financial support through the Inodonesian Education Scholarship (BPI) while I was a student at Universitas Pendidikan Indonesia (UPI).

Author Contributions
All authors contributed to writing this article.

Funding
No external funding.

Conflicts of Interest
No conflict interest.

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