

The Effect of Scaffolding Strategies on Learning Outcomes in Science Learning: A Systematic Literature Review

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Received: July 24, 2024

Revised: September 08, 2024

Accepted: January 25, 2025

Published: January 31, 2025

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DOI: [10.29303/jppipa.v11i1.8628](https://doi.org/10.29303/jppipa.v11i1.8628)

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Abstract: Science learning must be designed so that students can understand natural phenomena that are constantly changing. This study aims to explore scaffolding strategies related to research trends, influence on learning outcomes, appropriate learning models, research designs used, and profiles of the use of scaffolding in science learning at various levels of education. The research is a systematic literature review (SLR) to collect, analyze, and compile findings on scaffolding strategies in science learning. The literature review results show that scaffolding strategies are effective in helping students understand scientific concepts better. Providing structured scaffolding to students effectively improves students' learning outcomes. The literature review results show that in the 2014-2024 time span, research on the application of scaffolding mostly uses quantitative methods with a non-equivalent control group design. The learning model that is widely used with scaffolding is Problem-Based Learning (PBL). Scaffolding positively impacts students' cognitive and affective learning outcomes, concept understanding, science process skills, argumentation skills, critical thinking skills, higher-order thinking skills (HOTS), learning independence, learning motivation, scientific literacy, problem-solving skills, and misconceptions. The scaffolding strategies can improve science learning effectively.

Keywords: Critical thinking skills; Higher-order thinking skills; Learning outcomes; Problem-based learning; Scaffolding

Introduction

The 21st-century science learning equips students with critical thinking, problem-solving, and decision-making skills to address global challenges (Gencer & Doğan, 2020; Sadhu & Laksono, 2018). Integration of critical thinking skills into science education can enhance students' ability to analyze and apply scientific concepts in real-world contexts, as well as improve students' scientific literacy (Guffey et al., 2016). In addition, the integration of technology and STEM skills prepares students to meet the demands of the Fourth Industrial Revolution, enhances digital literacy, and enables active participation in the job market (Chen & Chuang, 2020). Experiential learning, cross-disciplinary

collaboration, and sustainability make science education a vital tool to address global issues such as climate change and health crises and foster a sense of responsibility in students (Kyle, 2020; Verawati, 2023). This science learning can form an adaptive, creative generation ready to contribute to global innovation and problem-solving (Margot & Kettler, 2019; Smith et al., 2022).

Science learning in schools faces several challenges that hinder learning effectiveness. Low student learning outcomes are often caused by monotonous and teacher-centered learning models that limit active student involvement (Mariamah et al., 2022). This is reflected in international assessments such as PISA, where Indonesian students' performance in science is below the

How to Cite:

Azzaroiha, C., Redhana, I. W., & Suma, K. (2025). The Effect of Scaffolding Strategies on Learning Outcomes in Science Learning: A Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, 11(1), 45-55. <https://doi.org/10.29303/jppipa.v11i1.8628>

global average (Rahmayanti, 2023). In addition, the lack of adequate laboratory facilities and practical equipment can hinder understanding abstract concepts from the material being studied (Festiyed & Iswari, 2018; Rahmadani, 2017). Curriculums that are too dense and focused on test scores and lack relevance to real-world challenges such as climate change or technological advances also reduce students' motivation to learn (Soeharto et al., 2019). Differences in students' abilities that are often ignored due to a uniform teaching approach are also an obstacle (Meganita et al., 2022).

Science teachers have implemented innovative approaches to address low students' learning outcomes, with scaffolding emerging as an effective strategy for improving conceptual understanding and students' engagement. Scaffolding provides tailored, incremental support, helping students break down complex concepts into more manageable pieces, such as pushing a shopping cart to introduce Newton's laws before discussing the mathematical formulas (Petersen, 2022). The approach often includes visual aids, animations, and guiding questions to encourage critical thinking (Hamada & Hassan, 2016; Masava et al., 2022), as well as interactive tools such as simulations and step-by-step guides that further enhance engagement and confidence (Masava et al., 2022). Scaffolding is particularly effective for teaching abstract topics such as energy and force to improve understanding and facilitate collaborative learning, where students share insights in group work before moving on to independent tasks (Ecevit, 2022; Lui, 2023). In addition, this method also develops important independent learning skills, equipping students for future academic success (Masava et al., 2022). Research shows that scaffolding promotes deeper understanding and better outcomes, making it an indispensable tool for creating more interactive and effective science education environments (Chen & Chuang, 2020; Madyawati et al., 2020).

Science teachers use scaffolding to enhance conceptual understanding and student engagement. Scaffolding is particularly effective for abstract topics such as energy and force, fostering understanding and collaborative learning before moving on to independent tasks (Ecevit, 2022; Lui, 2023). The strategy also develops independent learning skills, preparing students for future academic success (Masava et al., 2022). Research shows that scaffolding promotes deeper understanding and better outcomes, making it an essential tool in science education (Chen & Chuang, 2020; Madyawati et al., 2020).

Scaffolding strategies are effectively applied in various subjects to improve student learning outcomes by assisting according to student needs. In elementary mathematics courses, scaffolding helps students

understand the concept of fractions and connect abstract concepts with concrete representations (Ikawati, 2020; Rindengan & Rindengan, 2019). In secondary schools, scaffolding is used in science lessons to teach the concept of photosynthesis through diagrams, simple experiments, and structured questions, which enhances student understanding and engagement (Belland et al., 2017; Pol et al., 2018). In high schools, scaffolding is applied in English lessons to improve essay writing skills by providing a structured framework, guidance, and feedback, which enhances students' learning outcomes and self-confidence (Alrawili et al., 2020; Dermawan & Sunarno, 2018). The flexibility of scaffolding across subjects demonstrates its effectiveness in enhancing understanding of independent learning skills and preparing students to face academic challenges (Masava et al., 2022; Tran & Nguyen, 2021), making it an important approach in education.

Literature study research on the effect of scaffolding on learning outcomes is widely carried out in mathematics subjects (Bawadi et al., 2023; Kusmaryono & Wijayanti, 2020). However, research on the effect of scaffolding strategies on learning outcomes in science learning has not been conducted by previous researchers. This research needs to be done considering that scaffolding is one of the learning strategies that can provide gradual support to students and help them understand complex concepts through interactions with teachers or peers (Purwasih & Rahmadhani, 2022).

Based on the description above, the problem formulations to be answered through this research are as follows: What research trends apply scaffolding strategies in science learning?; What research designs use scaffolding strategies in science learning?; What are the learning models that use scaffolding strategies in science learning?; What are the learning outcomes affected by scaffolding strategies in science learning?; Does the scaffolding strategy affect students' learning outcomes in science learning?; and What is the profile of strategy implementation at the education level?

Method

This SLR process uses the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method to evaluate and filter relevant articles on the effect of scaffolding strategies on science learning. The detailed SLR procedure is shown in Figure 1. The first step is to determine the research needs and set a clear objective to identify the effect of scaffolding strategies on learning outcomes in science learning. The main keywords used in the article search include "scaffolding learning," "scaffold*," "learning outcome," and "science learning." The combination of keywords is

done with Boolean operators such as AND and OR to ensure optimal search coverage.

Using the Publish or Perish search engine, data was collected from two databases, Google Scholar and Crossref. The articles searched were limited between 2014 and 2024. The next stage is the identification stage, which aims to check the same article. The same article will be excluded from the analysis. Furthermore, the screening stage of the article title is based on the following criteria: the title contains scaffolding strategies in science learning and uses Indonesian and English. The article comes from international and national journals of at least Sinta 3 and is not a literature study. The next screening stage is carried out by reading the article's abstract. Articles that are included are based on the following criteria, namely: the results of the study explain the influence of scaffolding strategies on science learning, the study uses qualitative, quantitative, and research and development methods, and research areas at the primary and secondary education levels. Articles that pass this stage are then reviewed in full to ensure that the article meets all the inclusion criteria that have been set. To maintain objectivity, the review process is carried out by two researchers simultaneously. If there are differences in the review results, a discussion is held to reach an agreement. This aims to minimize bias and ensure the accuracy of the selection process.

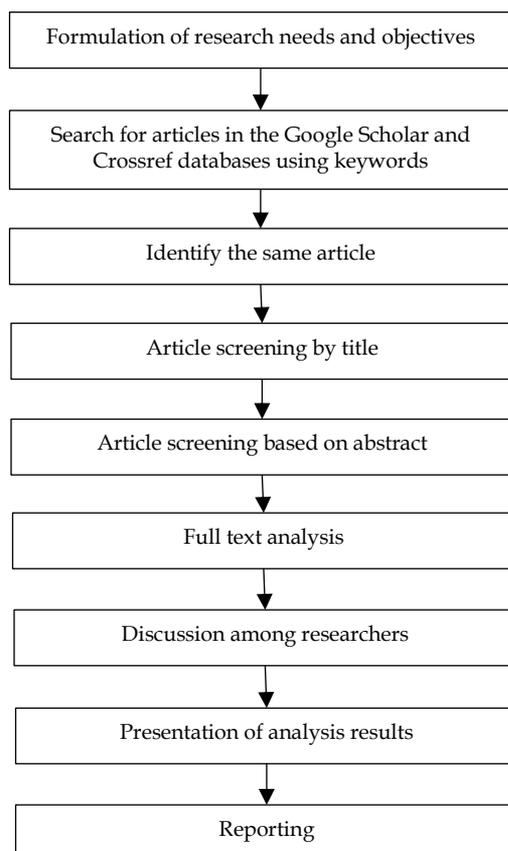


Figure 1. Data collection, analysis, and reporting procedures

The data obtained are presented systematically in tables and/or graphs to facilitate interpretation and report preparation. The article selection process is described in a PRISMA diagram that includes the number of articles found in the initial stage, the number of articles excluded during screening, and the number of articles fully analyzed and finally used in the study. The final result of this process is a comprehensive report on the effect of scaffolding strategies on science learning. With these steps, the SLR process is carried out systematically, transparently, and accountably.

Result and Discussion

This literature review aims to provide information related to research trends that apply scaffolding strategies in science learning, research designs using scaffolding strategies in science learning, the learning models using scaffolding strategies in science learning, types of learning outcomes affected by scaffolding strategies in science learning, the effect of scaffolding strategy on students' learning outcomes in science learning, and the profile of strategy implementation at the education level.

Articles were searched from Google Scholar and Crossref databases. This search resulted in 1000 articles. Then, identification was carried out to find similar articles, resulting in 100 articles. The 900 articles that did not have similarities were then reviewed based on their titles. The criteria used to select articles were articles containing scaffolding strategies in science learning, articles written in Indonesian and English, articles from journals, and articles only from research results. This screening process resulted in 177 eligible articles. The screening process was continued by reading the abstract. Article selection was based on several criteria: articles explaining the influence of scaffolding strategies on science learning, articles on qualitative, quantitative, and research and development research methods, and the screening process resulted in 40 articles. The entire identification and screening process is described in detail in Figure 2.

A total of 40 articles selected in the initial stage of the selection process were reviewed in depth by both researchers simultaneously. This review process was carried out carefully to ensure that each article met the previously determined inclusion criteria and was relevant to the focus of the research. If there were differences of opinion or review results between the two researchers, intensive discussions were conducted to align perceptions and reach a standard agreement. This collaborative approach aims to minimize subjectivity, increase the validity of the review results, and ensure that each selected article contributes significantly to the

research's analysis and findings. Thus, this review process not only prioritizes caution but also academic integrity in the preparation of the SLR. The results of the review can be presented in the following paragraphs.

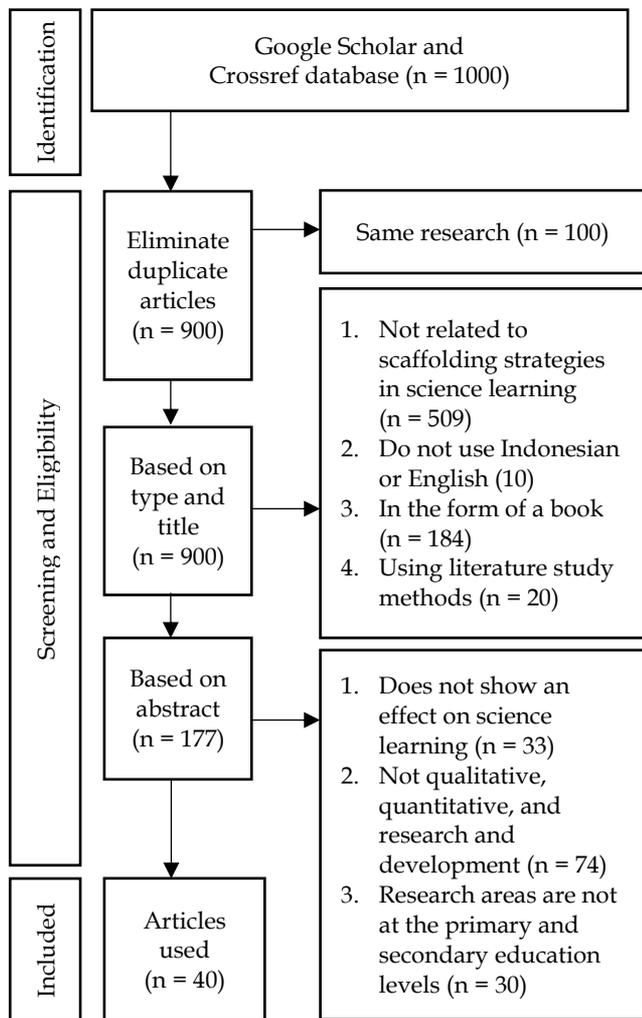


Figure 2. Diagram PRISMA (Haq et al., 2019)

Scaffolding strategies have positively impacted students' learning outcomes for the last ten years. This

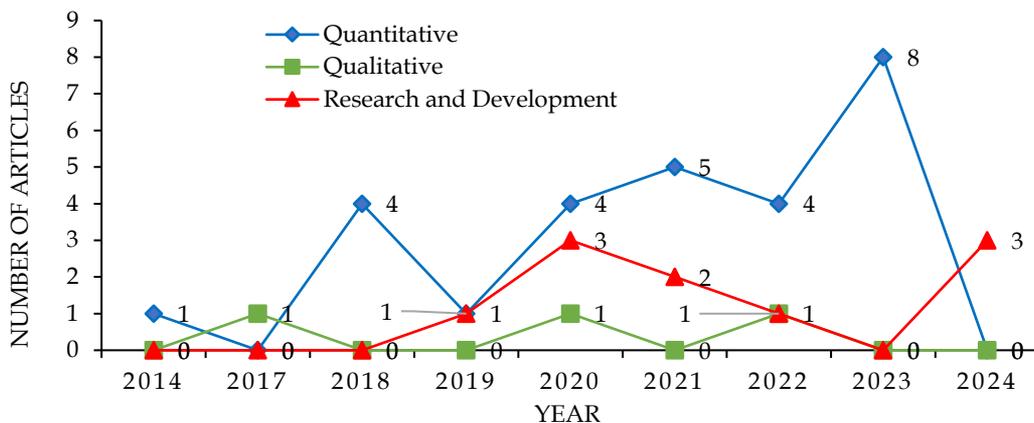


Figure 3. Trends in the use of scaffolding strategies for 2014 - 2024

strategy helps students understand complex concepts in a deeper and more structured way, improving their understanding of the subject matter. This strengthens their understanding of the subject matter and develops problem-solving and critical thinking skills. In addition, scaffolding strategies encourage students' learning independence by providing appropriate support according to their level of understanding, thus helping them to learn independently in the future (Tuada et al., 2020). Apart from the cognitive aspect, scaffolding also contributes to the development of student's social and emotional skills by providing a supportive learning environment to receive learning (Padilah & Novtria, 2023).

However, one study shows that the use of scaffolding in learning does not have a significant effect on students' learning activities. According to Suroyalmilah et al. (2018) some students still fall into the medium category, meaning that these students are active when learning takes place. Overall, scaffolding strategies improve cognitive abilities, empower students to be actively involved in the classroom, and foster learning independence (Suparno et al., 2020).

The literature review results show the range of years of research using scaffolding in science learning. Figure 3 presents the relationship between the year of publication and the number of publications related to research using scaffolding strategies in the last 10 years (2014-2024).

The results in Figure 3 show the trend of using research methods that apply scaffolding in science learning. The use of quantitative methods increased in the range of 2019 - 2023, especially in 2023. Meanwhile, the use of qualitative methods did not experience a significant increase in a certain range of years. Qualitative methods had the lowest results among other methods. From 2020 to 2023, the use of development methods decreased but increased in 2024.

The results of the literature review show a variety of research methods used to examine the impact of using scaffolding on learning outcomes. The research methods that use scaffolding strategies are shown in Table 1. Based on Table 1, quantitative research is the most common method researchers use to investigate the effect of scaffolding strategies on learning outcomes. The results of the literature review show a variety of quantitative research designs applied, such as non-equivalent control group design, pretest-posttest control group design, one group pretest-posttest design, and one group posttest-only design. The most widely used research design is the non-equivalent control group design. The design is considered more accurate in some research contexts because it can control variables affecting research results. The use of different research methods shows the diversity of learning outcomes achieved by students.

Table 1. Research methods used

Research Methods	Number of Articles	Percentage (%)
Quantitative	30	75.00
Qualitative	3	7.50
Research and development	7	17.50

Most of the studies used scaffolding as a strategy in science learning. Scaffolding is used as an aid when applying learning models. Some learning models often applied with scaffolding are shown in Figure 4.

Learning models that use scaffolding as a strategy to improve learning outcomes include Team Game Tournament (TGT) (2.5%) (Arindasandy et al., 2023), Simulation Based Learning (SBL) (2.5%) (Yang & Su, 2020), Sharing Task Learning (STL) (2.5%) (Nurrohmah et al., 2020), Project Based Learning (PjBL) (5.0%) (Haryati et al., 2024; Yanti et al., 2023), Problem Based Learning (PBL) (12.5%) (Andi et al., 2021; Haidar et al., 2020; Panyapisit & Tiantong, 2018; Sari et al., 2024; Yuliawanti et al., 2019), Learning Cycle of Engagement, Exploration, Explanation, Elaboration, and Evaluation (LC 5E) (2.5%) (Cylindrica et al., 2021), Inquiry Based Learning (IBL) (10.0%) (Anggraini & Suciati, 2018; Arimas et al., 2022; Auliyani et al., 2023; Tiaradipa et al., 2020), Guided Inquiry, Reading, Sharing, Mind Mapping, and Communication (GIReSiMCO) (2.5%) (Senisum et al., 2022), Game Based Learning (GBL) (10.0%) (Chang & Yang, 2023; Eveline et al., 2019; Lee et al., 2023; Suparno et al., 2020), Discovery Learning (DL) (7.5%) (Dewi et al., 2018; Maysara et al., 2024; Ningsih et al., 2024), Cooperative Learning (CL) (5.0%) (Astuti & Sianipar, 2023; Imaningtyas et al., 2018), and Children Learning in Science (CLIS) (2.5%) (Fitriyah et al., 2022). Meanwhile, articles that applied scaffolding strategies

but did not mention the learning model used were 35.0%.

Based on the data in Figure 4, the learning model most often used together with scaffolding strategies is PBL. The learning process with the PBL model assisted by scaffolding begins with introducing a complex problem that makes students explore and apply relevant concepts to complete a problem-solving task. This process aims to integrate content learning with practical application in real problem-solving while providing appropriate support to students' abilities through scaffolding (Fitriyah et al., 2022). Scaffolding-assisted PBL deepens concept understanding and develops students' critical thinking skills, collaboration, and learning independence (Mita & Ihsanudin, 2024).

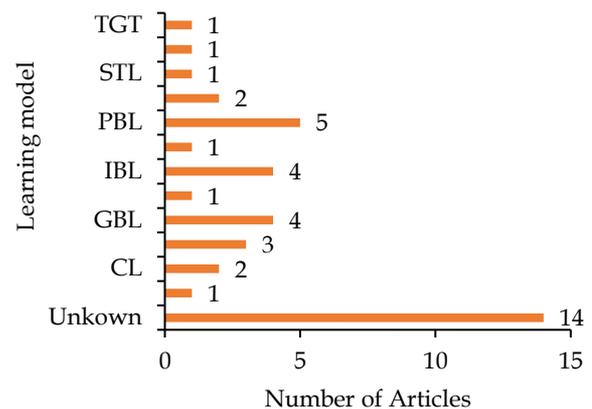


Figure 4. Learning model combined with scaffolding strategy

PBL has some weaknesses that need to be considered in its implementation, such as the need for a lot of time in implementation and the readiness of students to engage in problem identification, investigation, and discussion (Tyas, 2017). However, learning that uses scaffolding in learning models such as TGT, SBL, STL, PjBL, PBL, LC 5E, IBL, ReSiMCO, GBL, DL, CL, and CLIS shows a significant effect on students' learning outcomes in science learning.

Scaffolding is a learning strategy that supports and facilitates learning. Scaffolding is not a completely stand-alone learning approach but a technique or method applied in various learning models, such as PBL, IBL, or CL (Syukri & Endang, 2014). Scaffolding assists students in overcoming learning challenges or tasks by providing support, guidance, and structure appropriate to their level of understanding (Kusmaryono, 2021). Thus, scaffolding can be said to be one of the strategies that can support the effectiveness of students' learning process.

The results of the application of scaffolding strategies in learning have a significant impact on students' learning outcomes. Learning outcomes that are

positively affected by the application of scaffolding strategies are shown in Figure 5.

Scaffolding positively impacts students' cognitive and affective learning outcomes, concept understanding, science process skills, argumentation skills, critical thinking skills, HOTS, learning independence, learning motivation, scientific literacy, problem-solving skills, and misconceptions. Overall, the application of scaffolding facilitates the learning process and can improve students' learning outcomes in terms of cognitive, affective, and psychomotor (Ningsih et al., 2024). Four articles can improve more than one students' learning outcome, including being able to enhance affective learning outcomes and creative thinking (Lee et al., 2023), cognitive learning outcomes and scientific literacy (Sari et al., 2024), learning outcomes (cognitive) and process skills (Senisum et al., 2022), concept understanding, and achievement motivation (Cylindrica et al., 2021).

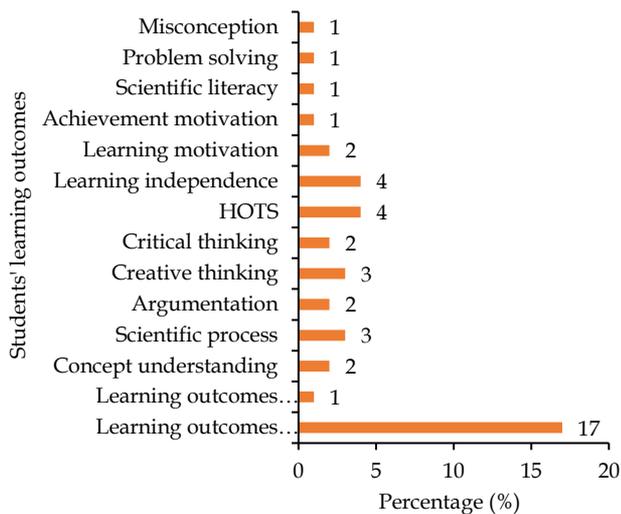


Figure 5. Learning outcomes obtained after applying the scaffolding strategy

Applying scaffolding in science learning helps students achieve a more profound understanding and better retention of the subject matter. According to Anggraini & Suciati (2018), by providing structured and continuous guidance, students can overcome obstacles in understanding complex concepts and improve their ability to master the material (Chang & Yang, 2023).

From an affective perspective, scaffolding can increase students' learning motivation to learn by providing challenges appropriate to their ability level and adequate support (Yang et al., 2022). Students' learning motivation is also supported by providing positive feedback that builds confidence (Suparno et al., 2020). This helps create a positive learning environment and triggers students' interest in the subject matter (Isoe et al., 2022). Scaffolding helps students learn

independently by providing the skills and strategies to tackle difficult tasks and find solutions independently (Tuada et al., 2020).

Scaffolding strategies can be applied to several levels of education. Based on Figure 6, the effect of scaffolding strategies in science learning can improve students' learning outcomes in senior high school (SHS) with a percentage of 62.5%. Scaffolding can also be applied at the elementary school (ES) and junior high school (JHS) levels, with a percentage of 22.5% and 15%, respectively.

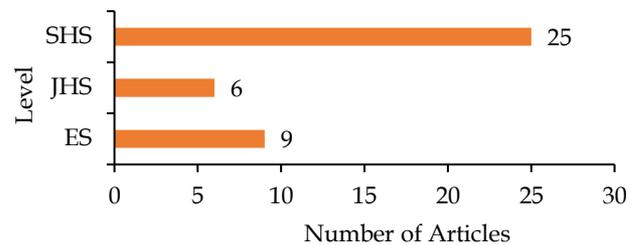


Figure 6. Application of scaffolding strategies at the education level

The application of scaffolding at the elementary level can have a good impact on learning outcomes, argumentation skills, scientific literacy, and creative thinking skills (Arimas et al., 2022; Chang & Yang, 2023; Fokong, 2023; Grimm et al., 2023; Haidar et al., 2020; Lee et al., 2023; Tegeh et al., 2021; Yang et al., 2022; Yang & Su, 2020). In general, scaffolding in elementary schools aims to provide the necessary support so that students can achieve a deep understanding of the subject matter, develop creativity, and gain confidence in learning (Purwasih & Rahmadhani, 2022).

According to Grimm et al. (2023), at the elementary level, scaffolding can be adapted to students' initial conditions to increase the effectiveness of their learning. Considering students' differences, the scaffolding approach can provide appropriate support to help students develop the required reasoning skills.

The application of scaffolding at the junior high school level often uses various learning models to facilitate students' understanding, such as PjBL, DL, and CLIS (Astuti & Sianipar, 2023; Chang & Yang, 2023; Dewi et al., 2018; Fitriyah et al., 2022; Isoe et al., 2022; Yanti et al., 2023). The application of scaffolding in junior high school aims to support students in overcoming more complex learning challenges. According to (Fitriyah et al., 2022), scaffolding strategies provide the necessary support for students to understand scientific concepts in depth and apply critical reasoning in the context of science learning.

The results in Figure 6 show that scaffolding strategies are most widely applied at the high school level. The application of scaffolding in high school aims

to develop relevant skills in everyday life. According to Sari et al. (2024), scaffolding strategies assist students in understanding scientific concepts in depth and developing their critical thinking skills through active exploration in problem-solving. This is because scaffolding can provide step-by-step guidance and constructive feedback.

Conclusion

Scaffolding has a positive effect on improving students' learning outcomes. The literature review results show that scaffolding strategies are effective in helping students understand scientific concepts better. Scaffolding strategies provide gradual and structured support to students through guiding questions, additional reading materials, or feedback. The literature review results show that in the 2014-2024 timeframe, research on scaffolding strategies mostly uses quantitative methods with a non-equivalent control group design. The learning model that is widely used together with scaffolding is PBL. Scaffolding positively impacts students' cognitive and affective learning outcomes, concept understanding, science process skills, argumentation skills, critical thinking skills, HOTS, learning independence, learning motivation, scientific literacy, problem-solving skills, and misconceptions. The implications of this review indicate that educators and researchers need to continue to integrate scaffolding strategies in science learning practices to improve learning effectiveness.

Acknowledgments

The authors would like to express their highest thanks to Jurnal Penelitian Pendidikan IPA for publishing this article.

Author Contributions

C. A. searched for articles, analyzed the data, and wrote the manuscript; K. S. reviewed the manuscript; I W. R. reviewed and submitted the manuscript. All authors have read and approved the published version of the manuscript.

Funding

This research was funded by the Research Directorate, Technology, and Community Service, with grant number 081/E5/PG.02.00.PL/2024.

Conflicts of Interest

The author declares no conflict of interest in writing the article.

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