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The Use of Scaffolding in Physics Learning: A Systematic Review

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ABSTRACT
The scaffolding strategy has been researched in 17 countries around the world regarding its effectiveness in helping improve students' competence in learning. This strategy is implemented directly with the learning model and integrated into physics learning media. The purpose of this study is to provide a description of research trends, methods, and findings on the use of scaffolding in the physics learning process. Systematic Literature Review (SLR) is the method of this research. Article data in the last 6 years (2018–2023) was collected from the Scopus database with the help of the Publish or Perish (PoP) 7 program and the Science Direct database. There were 52 articles selected using the PRISMA technique. Future research has the opportunity to develop learning media that contain scaffolding strategies to support a meaningful physics learning process. The focus of future research can lead to increased learner independence and 21st century skills through scaffolding strategies implemented in various forms of learning media development.

INTRODUCTION

Learning is a process involving a learning model. Within learning, there are strategies to enhance the competence of the student with approaches, methods, and learning techniques. Teachers try to present interactive and meaningful learning to improve the learning outcomes of the students. Active learning is more effective than conventional learning [1]. Therefore, educators need to design learning strategies carefully. One method that educators use as a learning strategy is scaffolding.

Scaffolding is a form of assistance that learners gradually receive during the learning process [2]. Generally, scaffolding aims to enhance the abilities of learners [3]. The strategy has also been used to improve writing skills and introduce natural sciences in early childhood [4]. Based on the literature review, physics learning also uses scaffolding as a strategy in teaching. Scaffolding is more likely to improve problem-solving skills [5] [6], critical thinking [7] [8] [9], high-level thinking [10] [11] [12] [13], creative thinking [14], metacognition [15] [16] [17] [18], student learning motivation [17] [18] [19], and learning independence [20] [21]. The findings are based on literature studies in the period 2018–2023.

Studies on scaffolding have been conducted in various countries with diverse samples. Its implementation in learning is an interesting topic to analyze. 21st century learning demands the active role of teachers as facilitators and learners [22]. The utilization of technology is an interesting thing to do. Especially in physics learning, animation computing technology and virtual labs help educators teach and students understand the phenomena that occur. Research on the development of learning media is also carried out to improve the competence of students through a learning strategy.

The use of scaffolding strategies has been integrated into physics learning media products such as e-modules [23] [24], augmented-reality [11], game-based learning [3], android media learning [10] [21], and the utilization of the PhET virtual lab [25] [26] [27] [28] [29]. In addition to learning media products, scaffolding strategies have also been integrated with learning models such as group investigation [30] [31], simulation based learning [32], team-based learning (TBL), case-based learning (CBL) [33], blended learning [34], discovery learning [1], and project-based learning [35]. This proves that the role of scaffolding is an interesting trend in educational research.

Based on the collection of previous research and to the author's knowledge, publications on systematic literature review by combining bibliometric analysis assisted by Vosviewer in the use of scaffolding in the physics learning process have never been done. Therefore, this systematic review analysis will show opportunities for further study and product development in the utilization of scaffolding in the field of physics education. This study aims to provide a description of research trends, methods, and findings on the use of scaffolding in the learning process. Future researchers can use the advantages of these objectives to close the gaps and strengthen the findings regarding the use of scaffolding strategies.

METHOD

Research Design

This research study uses the Systematic Literature Review (SLR) method with the help of Vosviewer to map the findings. This research study presents a description, review, and analysis of the use of scaffolding in physics learning. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) technique is used in this study to identify, screen, test eligibility, enter data, analyze, and present in narrative form.

Inclusion and exclusion criteria selection of publications

Five things were done in the inclusion and exclusion stage, namely: i) Scopus-indexed articles; ii) Articles searched contain the use of scaffolding in learning; iii) The media used for literature search in the Scopus database uses the Publish or Perish 7 program by entering the API key. In addition, literature searches were also carried out through the Science Direct database; iv) The literature reviewed was in the form of scientific articles and conference proceedings; v) The publication of articles is limited to 2018–2023.

Screening and eligibility assesment for data analysis and PRISMA flow diagram

Screening is carried out on aspects of titles, keywords, and abstracts that are specific to the theme of scaffolding. The search results obtained 760 research articles in the last 6 years, namely 2018–2023. The keywords used in the search through the Scopus and Science Direct databases are described in Table 1.

Of the 760 articles found, further filtering was carried out using the PRISMA technique. The 760 articles were exported to Excel and then identified for duplication. There are 282 articles that have been filtered for duplication. Furthermore, articles that are relevant to the use of scaffolding are further examined, and 86 articles are obtained. Further screening was carried out to obtain articles that were closely related to the implementation of scaffolding in education, so that 65 articles were obtained. The next selection process was carried out by reviewing the open access to the articles. There were 13 articles that did not have free open access, so only 52 articles will be reviewed further in this study.

The screening process for these articles can be observed through the PRISMA diagram in Figure 1.

Table 1. Finding of Article

No.	Keyword	Quantity	Source
1	Scaffolding method	200 articles	Scopus database through Publish or Perish 7
2	Scaffolding physics	145 articles	
3	Scaffolding physics student	200 articles	
4	Scaffolding physics student	215 articles	Science direct database
Total		**760 articles**	

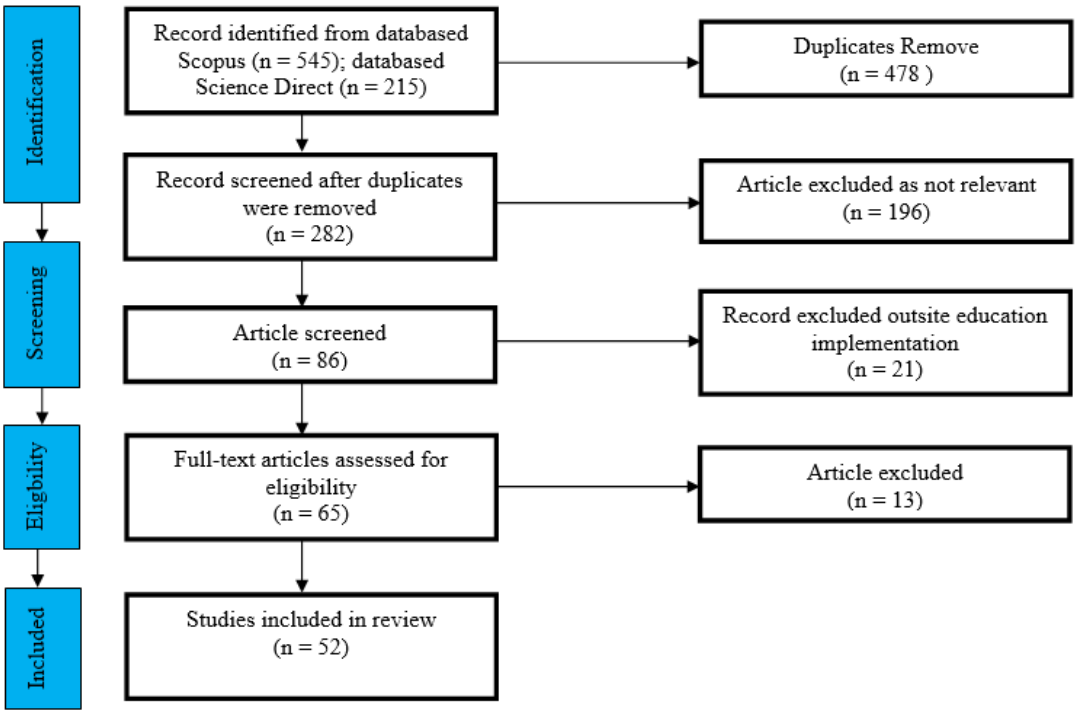

Fig 1. *PRISMA Flow Diagram*

A total of 52 articles selected as part of this study were entered into the Mendeley program. The articles were then exported to RIS format for bibliometric analysis using Vosviewer version 1.6.17.

RESULTS AND DISCUSSIONS

This study reviewed 52 articles that had been selected using the PRISMA technique. The research examined the use of scaffolding in learning. An analysis of the number of articles examining the use of scaffolding in a 6-year period (2018–2013) is presented in Figure 2.

Figure 2 shows an increase from 2018 to 2019, followed by a decrease in the number of articles that examine the use of scaffolding in learning. Publications that dominate in the last 6 years include Journal of Physics: Conference Series, AIP Conference Proceedings, Journal for the Education of Gifted Young Scientists, International Journal of Child-Computer Interaction, and International Journal of Teaching and Teacher Education.

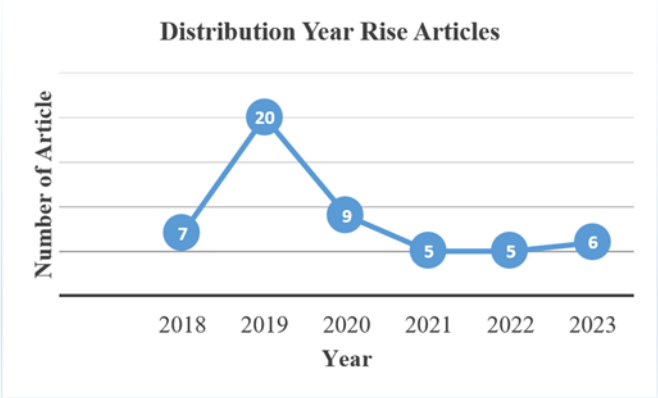

Fig 2. *Number of Documents Relevant to the Topic of Scaffolding every year for a period of 6 years (2018-2023)*

From the 52 selected articles, the author also analyzed the distribution of countries and the number of research articles on the use of scaffolding in learning. The results of the analysis are presented in Figure 3 below.

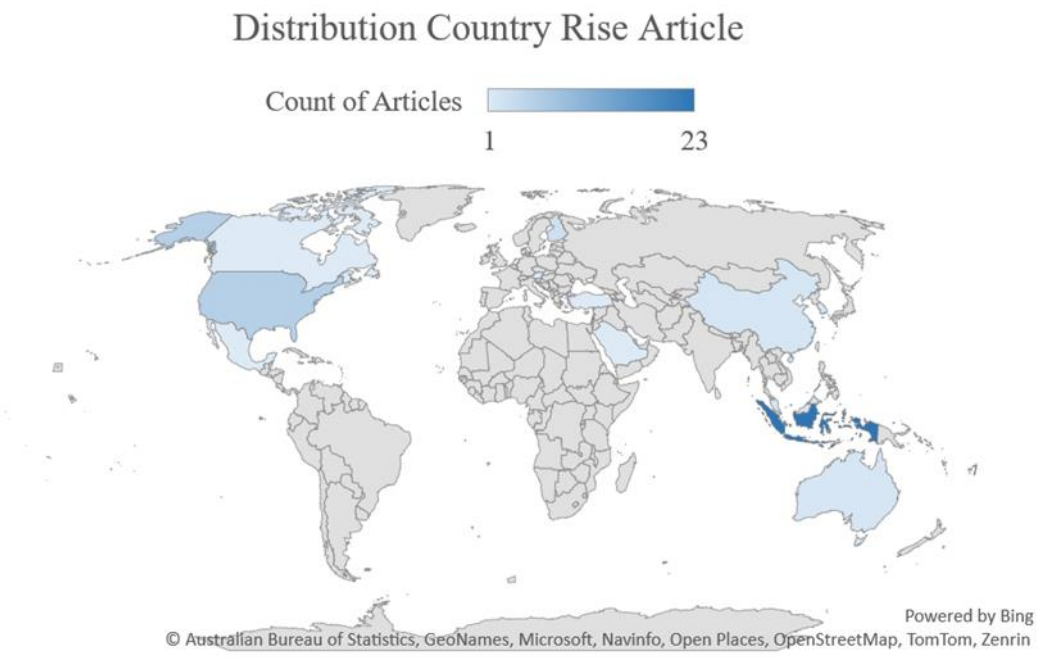

Fig 3. *Distribution Country Number of Documents Relevant to the Topic of Scaffolding every year for a period of 6 years (2018-2023)*

Figure 3 presents the distribution of countries that published educational research on the use of scaffolding in learning. There are 17 countries that discuss the use of scaffolding in learning. In this section, we will discuss two main countries that discuss the integration of scaffolding strategies in learning, namely Indonesia and the USA. In Indonesia, there are 23 findings that discuss the use of scaffolding strategies with three categories of respondents. The first category is undergraduate students. The use of scaffolding is aimed at improving learning outcomes, critical thinking skills, problem solving skills, higher order thinking skills, metacognitive skills, and concept understanding of the students. The second category of respondents is upper secondary level students, at this level the use of scaffolding is applied as a strategy that can improve higher order thinking skills, increase students' learning independence, critical thinking skills, concept understanding, science process skills and problem solving skills. In addition, scaffolding strategies in Indonesia are also applied to

educators as the third category. Educators are expected to improve their pedagogical skills, critical thinking, and learning strategy analysis. The study of this is very relevant to the challenges of 21st century education [36]. Learners are expected to be able to adapt to a dynamic life and be able to solve daily problems in order to create a high quality of life. The most research on scaffolding is also in the USA with 6 research articles. Two of them discuss how this strategy is used in physics learning. The research respondents lead to high school students, educators and students at public universities. This strategy is used by teachers in the USA to help students understand physics concepts and computational thinking skills on the subject of kinematics and Newton's laws.

Bibliometic Vosviwer Analysis: Network Analysis of the Keyword Cooccurrences
Network analysis uses an overall word count to identify influential title words. This analysis uses the Vosviewer program. The results are as shown in Figures 4 and 5.

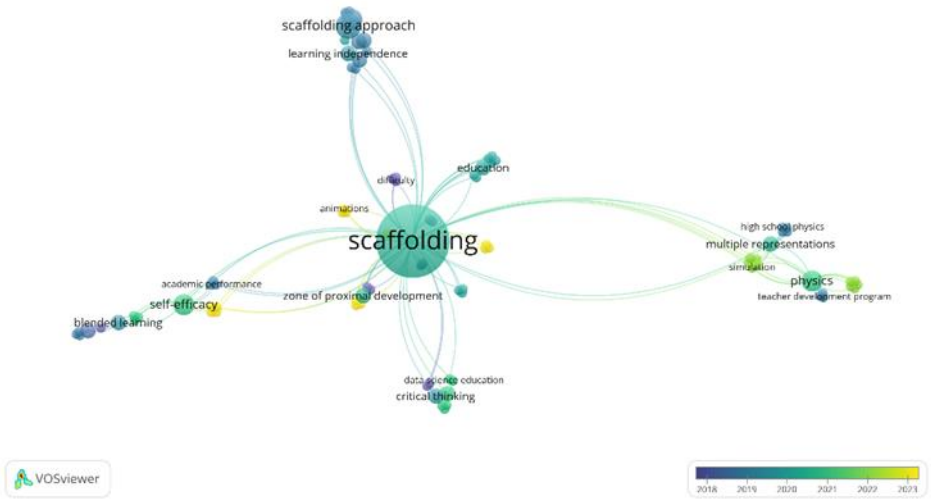

Fig 4. *Overlay visualization of network plot of keyword data/research title related to the topic scaffolding*

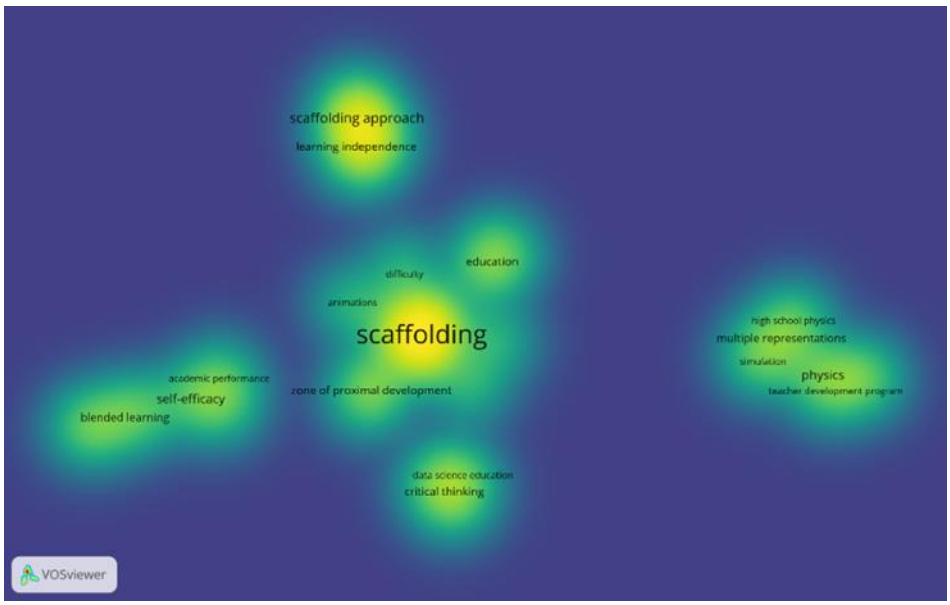

Fig 5. *Density visualization of network plot of keyword data/research title related to Scaffolding*

Figures 4 and 5 show the network analysis and visualization density with Vosviewer, indicating that the study of scaffolding is very close to other educational study themes such as academic performance, learning animation, blended learning, learning independence, critical thinking, physics teacher development, high school physics, and simulation. However, in this study, only the topic of the use of scaffolding in learning will be specialized to its application in physics learning.

Discussion: Scaffolding in Physics Learning

The 52 selected articles were then analyzed based on the type of methodology, research sample, and relevance to two research discussion topics, namely the use of scaffolding in the general scope of learning and the implementation of the use of scaffolding in physics learning. The research methodology used in the selected articles is shown in Figure 6

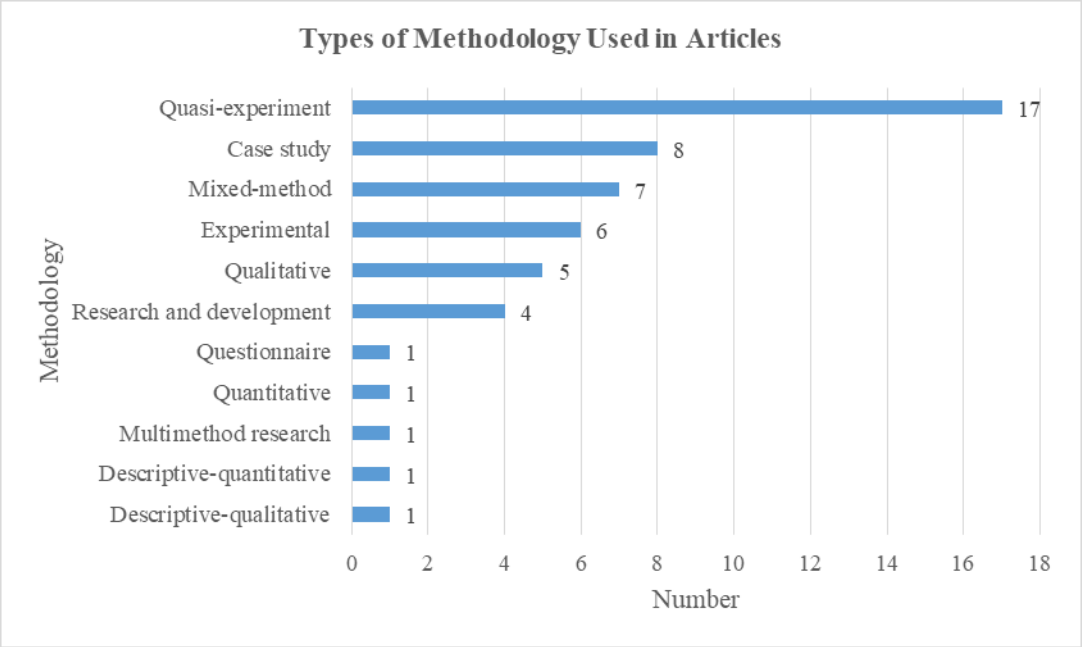

Fig 6. *Types of Methodology Used in Articles*

Five types of research methodologies often used in scaffolding research are quasi-experiment, case study, mixed-method, experimental, and qualitative. Quasi-experiment research methodology has dominated the study of scaffolding in the last six years. It provides accurate research on the effectiveness of using scaffolding strategies. The quasi-experimental method provides an opportunity for researchers to see contrasting effects between the experimental group using scaffolding strategies and the control class.

Research on the use of scaffolding strategies has been conducted on various samples. The research samples used in research on scaffolding are quite diverse, as shown in Figure 7.

Research on the topic of the use of scaffolding was conducted on 52 selected articles, some of which were conducted on both types of samples. The research sample was dominated by university students, with as many as 21 studies, or 36% of the total sample. The sample of high school students was 16 studies, or 27% of the total sample. Education at the high school and university levels is the main target for the application of scaffolding strategies. Through the analysis of selected research articles, it was found that the application of scaffolding strategies was also given to teaching teachers. A total of 11 studies used teaching teachers as research samples. It is applied to help educators understand the meaning of pedagogy, help understand the teaching profession program, and be implemented in educational workshops.

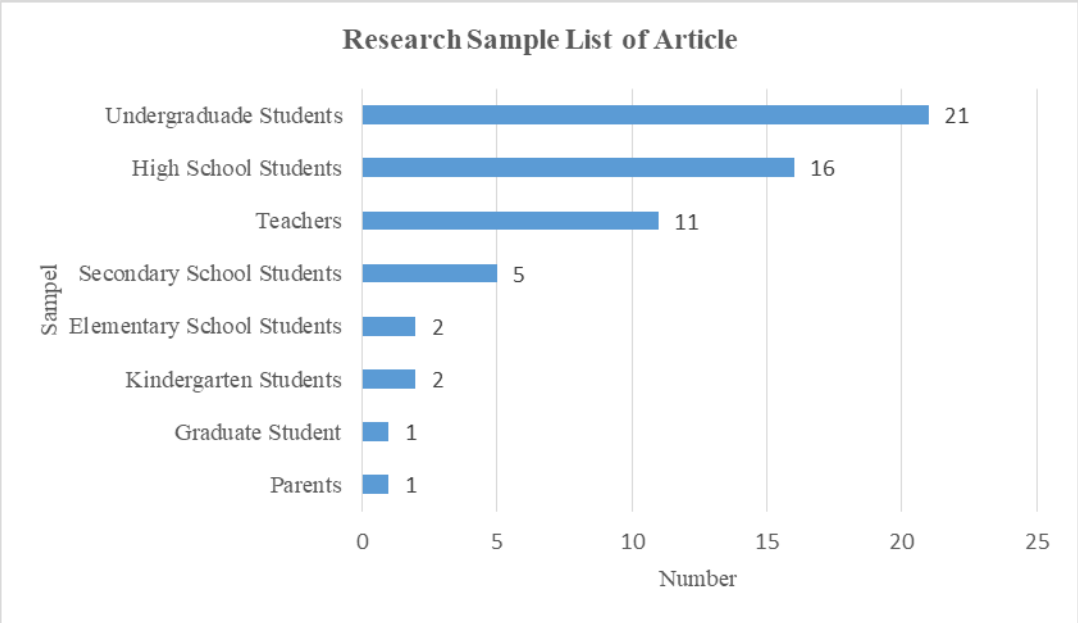

Fig 7. *Research Sample List of Articles*

The use of scaffolding in the general scope of learning

Scaffolding strategies can be used at all levels of education, from early childhood to graduate programs. At the early childhood and elementary school levels, scaffolding strategies have been applied to improve problem-solving skills with parent and teacher support [5] and are also used to practice writing skills [4]. Teachers at the preschool level are also treated with scaffolding strategies to improve innovative and impactful teaching [37], as well as pedagogical and cultural understanding [38]. Scaffolding is used in the learning process to help students get better at many skills, including: being motivated and interested in learning [3] [9] [19] [33] [39] [40], critical thinking [31], learning self-efficacy in computer learning [41], problem-solving [7] [9] [18] [42], and metacognitive skills that support long-term learning environments [15] [16]. The use of scaffolding strategies supports the learning model and assists teachers in reflecting on learning activities [14] [43] [44] [45].

These results strengthen the argument that scaffolding strategies can be applied in various fields of education. Efforts to improve learning outcomes, attitudes of independence, problem solving, and so on are the main attractions for educators to improve the quality of learning. The level of education from early childhood to university certainly wants the achievement of effective learning and provides an increase in learning ability for students. The successful application of scaffolding in learning early childhood literacy, computer programming, mathematics, chemistry, and pedagogy at the university level has been proven by the results of systematic reviews. The next discussion will discuss the implementation of scaffolding strategies in physics learning.

Implementation of the use of scaffolding in physics learning

Physics learning with a scaffolding strategy is an interesting thing to study. The physics learning process with scaffolding strategies has been proven to improve students' habits of mind effectively [46]. A scaffolding strategy in physics learning can improve problem-solving ability [47]. Another study stated that students who experienced scaffolding strategies had a higher percentage of visual representations built on their problem-solving solutions [48]. The development of physics worksheets integrated with scaffolding can effectively improve students' learning outcomes [49]. In terms of educators undergoing the Physics Teacher Development Program (TPD), scaffolding strategies are also effective in improving the quality of teachers, specifically in the aspect of Content Knowledge (CK) [50]. So that physics learning activities can be qualified and meaningful because educators have pedagogical strength, Physics with a variety of natural phenomena and events of motion of objects will be more easily understood by utilizing learning media.

Physics learning requires interactive media to support the achievement of learning objectives. The integration of scaffolding strategies in the utilization of PhET learning media can improve students' ability to understand concepts, learning independence, scientific process skills, and critical thinking [25] [26] [27] [28] [29]. In addition to using the PhET virtual lab, there is a study investigating students' strategies for improving the analysis of mathematical models during physics practicum with the help of the online scaffolding software tool InduLab [51]. The software has the ability to improve the understanding process of getting the right model for physics experimental data [51]. In addition to the utilization of software and virtual labs in scaffolding integrated teaching, research and development of physics learning media have also been conducted.

There are also 12 studies on physics learning media development conducted by implementing scaffolding strategies in it. Physics learning media with scaffolding include Android-based mobile learning, computer-based learning, augmented reality (AR) media, e-scaffolding with Learning Management System (LMS) schoology, and Google Classroom. The method used mostly uses quasi-experimentation with a one-group pretest-posttest design. The developed learning media aims to improve learning outcomes and self-efficacy [34], conceptual understanding [27] [52], Higher Order Thinking Skill (HOTS) [10] [11], Computational Thinking Skills (CTS) [53], student learning independence [21] [27], problem solving skills [23] [54], critical thinking and science process skills [25] [29]. In general, research findings state that learning media integrated with scaffolding strategies can improve the abilities of these learners.

CONCLUSION AND SUGGESTION

The results of this systematic literature study show the implementation of scaffolding strategies in learning. There is success in scaffolding strategies in improving various abilities of students in learning, such as increased learning motivation and engagement in the learning process of critical thinking skills, learning self-efficacy in computer learning, problem solving, and metacognitive abilities. The use of scaffolding strategies can support the learning model and assist teachers in reflecting on learning activities. Physics learning media that have been developed based on scaffolding strategies include android-based mobile learning, computer-based learning, augmented reality (AR) media, and e-scaffolding with learning management systems (LMS) such as Schoology and Google Classroom. Educational research on the effectiveness of scaffolding strategies is interesting material because it has been proven to be able to help educators in the learning process.

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