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Systematic literature review: analysis of implementation trends of STEM-based physics learning on dynamic fluid material

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Abstract
This study aims to examine the implementation of STEM-based physics learning on dynamic fluid material. This research falls under the Systematic Literature Review (SLR) category using the PRISMA method. The databases used include Google Scholar, Journal of Physics: Conference Series, and AIP Conference Proceedings. From these three databases, six relevant articles were obtained. Based on the research review conducted, the findings indicate that STEM-based physics learning can enhance students' mastery of concepts and creative thinking skills in dynamic fluid materials. This study implies that implementing STEM-based physics learning on dynamic fluid materials can enhance students' conceptual understanding and creative thinking skills, potentially fostering innovation in physics education in the future.

Keywords: fluid dynamics, physics learning, STEM

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I. Introduction

Learning in physics plays a crucial role in developing students' understanding of the fundamental principles of the universe and the natural phenomena that govern it. Not only does physics provide deep insight into the universe, but it also provides the basis for modern technology and innovations that affect our daily lives [1].

In an effort to improve the effectiveness of physics learning, various learning models have been developed and adopted. Integrating STEM (Science, Technology, Engineering, and Mathematics) learning is a prominent approach. STEM-based learning models emphasize applying physics concepts in real contexts involving technology, engineering, and mathematical science [2].

In addition, problem-based learning and inquiry-based learning models are also often used in physics learning. This model encourages students to actively engage in problem-solving and exploration of physics concepts through experimentation and research, thus improving their understanding of concepts and critical skills [3]. Integrating dynamic fluid material in physics learning with the STEM approach also provides opportunities for students to understand the basic principles of fluid in an applicative context and relevant to everyday life [4].

The concept of fluid mechanics, especially in dynamic fluids, has wide applications in daily life and technology [5], [6]. Understanding the properties of dynamic fluids is essential as it relates to natural and technological phenomena such as fountains, aircraft lifts, and hydram pumps. Although this material is often used in practical applications, students often find it difficult to learn. Several studies examining dynamic fluid material show that students have difficulty integrating the continuity equation and Bernoulli's law [7], lack understanding of Bernoulli's principle and its application [8], and have difficulty finding solutions to dynamic fluid-related problems in everyday life [9], [10].

Several researchers have conducted systematic literature reviews related to STEM-based physics learning or learning trend analysis studies on dynamic fluid material. Research by Dewi and Jauhariyah [11] describes a bibliometric analysis of the implementation of STEM-based physics learning in 2011-2021. Putra et al. [12] also conducted a similar study, which examined a meta-analysis of the effect of STEM on physics learning and students' concept understanding and creative thinking skills. In the same year, Wahdah et al. [13] also conducted a literature study on improving critical thinking skills in applying PjBL-STEM on dynamic fluid material. A bibliometric analysis conducted by Misbah et al. [14] related to research trends on dynamic fluids in physics learning shows that the United States is the most productive country on the topic.

Based on the previous explanation, literature studies related to the implementation of STEM-based physics learning in dynamic fluid material have still not been conducted. Therefore, we conducted a literature study that has two main objectives. The first objective is to find out how STEM-based physics learning is implemented, especially in terms of its success in improving concept mastery and creative thinking skills in a dynamic fluid material. The second objective is to discover various types of learning models that can be integrated with STEM.

The main contribution of this research is to fill the gap in the literature related to the implementation of STEM-based physics learning on dynamic fluid material and to explore the effectiveness of STEM-integrated learning models in improving students' concept mastery and creative thinking skills. This research is expected to provide new insights into the development of relevant and applicable learning methods in the context of physics education.

II. Methods

This study employs a Systematic Literature Review (SLR) approach using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method [15]. PRISMA was chosen because it ensures a structured and well-organized systematic review process [16]. The research steps were conducted through a literature review, which was presented following the format of previous systematic studies [17]. The databases for searching and selecting studies include Google Scholar, the Journal of Physics: Conference Series, and AIP Conference Proceedings.

Search Strategy. Databases used to conduct a systematic literature review included Google Scholar, Journal of Physics: Conference Series, and AIP Conference Proceedings. Google Scholar was chosen to search for national journals, while Journal of Physics: Conference Series and AIP Conference Proceedings were used to search for international journals. The database was selected based on title, keywords, year of publication, publication type, and issue. In the systematic review, the search string used was TITLE-ABS-KEY (“STEM” AND “Dynamic Fluid”).

Literature Review Selection. The literature review selection was conducted on May 19-21, 2024. The literature selection process is a crucial stage that involves several different steps. The initial search on STEM-based physics learning on dynamic fluid material resulted in 509 articles, which were then selected based on the inclusion criteria.

Inclusion and Exclusion Criteria. A selection stage was performed by setting inclusion and exclusion criteria in the relevant literature to select articles. The specified inclusion and exclusion criteria can be seen in Table 1.

Table 1. Inclusion and Exclusion Criteria Literature Review

Inclusion Criteria	Exclusion Criteria
1. The literature review consisted of journal articles and proceedings. 2. The articles and proceedings have been published and published. 3. Articles and proceedings were published in 2018-2024. 4. Research topics include STEM-based physics learning. 5. Research topics include STEM-based learning models on dynamic fluid material.	1. Literature review in the form of books, theses, papers, and reports. 2. Inaccessible articles. 3. Research topics that do not focus on physics learning. 4. Learning models that are not integrated with STEM. 5. Articles and proceedings that do not discuss dynamic fluid material.

After determining the inclusion and exclusion criteria, the next step is to select the articles to be reviewed. The data that has been obtained is then analyzed using the narrative method. This narrative method describes the implementation of physics learning with STEM-based models on dynamic fluid material and student abilities measured through applying STEM-based models.

Quality Criteria. Articles that met the inclusion criteria but did not conflict with any exclusion criteria were studied further if they met a set of characteristics or quality criteria. In this literature review, the quality criteria focused on articles that included STEM-based learning models, dynamic fluid materials, research samples of high school students, and articles that described the ability variables being measured. Of the 50 articles initially found in the initial database search, 44 were excluded based on the quality criteria, and in the end, only 6 articles were selected for further analysis. The data extraction process can be illustrated through the PRISMA method, as shown in Figure 1.

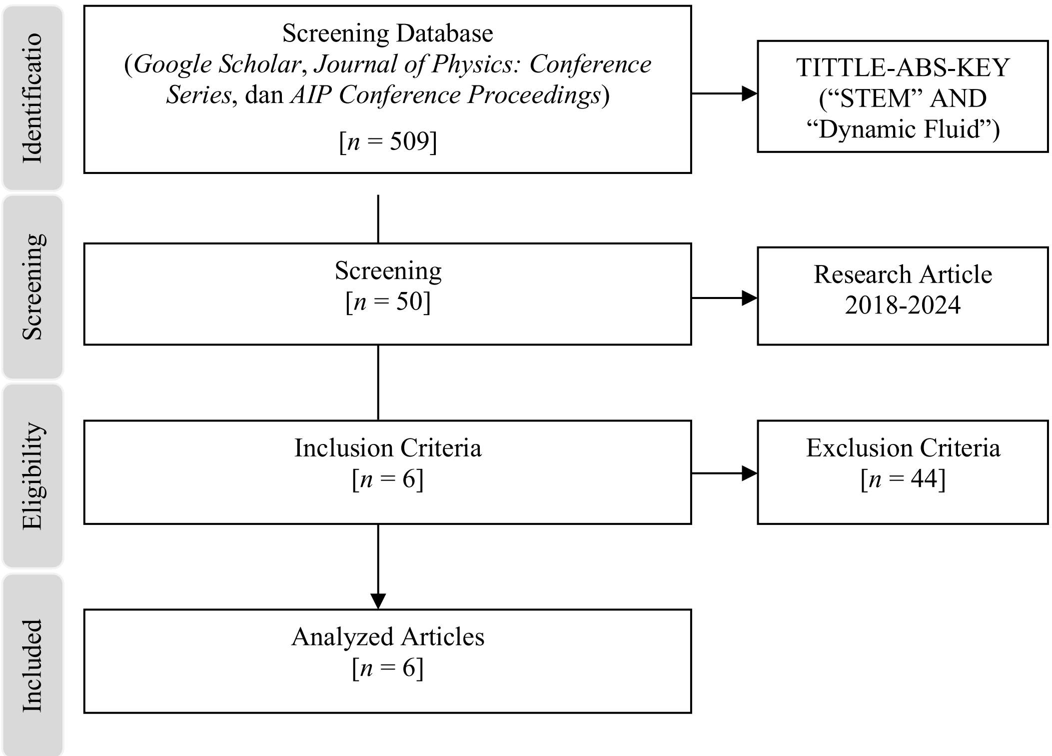

Figure 1. PRISMA Stages (Data Extraction Steps)

III. Results and discussion

Based on the analysis of the articles that have been reviewed, the STEM-based learning model on dynamic fluid material can improve students' mastery of concepts and creative thinking skills. The following is an explanation of the aspects of ability that can be improved through STEM-based learning models on dynamic fluid material:

Mastery Concept. Students' ability to apply their new knowledge to everyday situations is known as concept mastery. Students need mastery of dynamic fluid concepts to understand basic concepts, interpret their thinking about those concepts, and apply those concepts to solve conceptual and contextual problems. Students' problem-solving ability is often associated with concept mastery. Students who understand physics concepts well are expected to be able to solve problems.

Creative Thinking Ability. Active learning can improve students' creative thinking skills. Project-based Creative Learning (PCL) model, Problem-Based Instruction, Mind Map, and ERCoRe Learning are some of the learning approaches used to improve students' creative thinking abilities. However, some problems are encountered, such as only increasing fluency and elaboration and a long time to improve aspects of creative thinking. In contrast, some recommendations show that inquiry-based learning can improve students' creativity.

How is STEM-based Physics Learning Implemented on Dynamic Fluid Material?

This research uses the Systematic Literature Review (SLR) method using data from Google Scholar, Journal of Physics: Conference Series, and AIP Conference Proceedings. With the keywords "STEM" and "Dynamic Fluid", the search results from the three sources above obtained a total of 1364 articles with the following details: 493 articles from Google Scholar, 7 articles from Journal of Physics: Conference Series, and 9 articles from AIP Conference Proceedings. The articles were then selected based on criteria related to STEM-based physics learning on dynamic fluid material. The final selection results obtained 6 articles that fit the criteria. The six articles that have been selected are then analyzed in Table 2. Based on the analysis, the six articles mentioned above discuss learning models integrated with STEM on dynamic fluid. The research results contained in the articles show that STEM-based learning models can improve student abilities, such as concept mastery and creative thinking skills.

STEM-based Learning Model

Some STEM-based learning models on dynamic fluids based on the six articles presented in the Table 2, include:

1) **Problem-based STEM learning**
To improve the quality of education, integrated education in Science, Technology, Engineering, and Mathematics (STEM) is the right choice. STEM is a learning approach that combines elements of science, technology, engineering and mathematics into one learning process that can thoroughly improve students' knowledge and abilities. Problem-based STEM learning focuses on contextual problems. Problem-based STEM learning teaches students to face, analyze, and solve problems the teacher presents. This problem-based learning model is integrated into a broad learning approach for Science, Technology, Engineering, and Mathematics [18], [19].

2) **Guided Inquiry Assisted Module Integrated with STEM**
Guided inquiry learning emphasizes inquiry-based and student-focused learning, so the teacher's role is only as a facilitator in the learning process. This learning model uses authentic questions to generate new understanding [20]. Through guided inquiry learning, students can develop their conceptual understanding by reflecting, discussing and evaluating their own understanding [21]. Integrating STEM (Science, Technology, Engineering, and Mathematics) in guided inquiry supports students' future perspectives, assisting them in understanding concepts relevant to real-life problems.
Appropriate teaching materials must support guided inquiry learning as a scientific investigation. With the help of supportive teaching materials, students can create and discover experimental approaches independently. University Kebangsaan Malaysia uses the Teach Engineering module created by the University of Colorado to improve the science learning process. Based on STEM (Science, Technology, Engineering, and Mathematics) content knowledge, the Teach Engineering module features consisting of Think, Make, and Improve (TMI) can help bring learning into real-world problem-solving [22]. Teach Engineering modules can also support STEM (Science, Technology, Engineering, and Mathematics) integrated inquiry learning. Thus, the Teach Engineering module designed for STEM-integrated guided inquiry learning can improve students' understanding of physics concepts [22].

3) **IBL (Inquiry-Based Learning)-STEM Learning**
Inquiry-based Learning (IBL) is a learning model in which students act as researchers. By making questions, students will learn to think deductively and inductively. Research results show that inquiry-based learning can improve students' concept understanding [23] and learning achievement [24]. Research on inquiry-based learning proposes incorporating the STEM approach into dynamic fluid learning [25]. This approach requires contextualized learning that has a strong connection to the fields of science and technology and is based on experimentation without eliminating the elements of physical, process, and product learning.
It is expected that the application of inquiry-based learning that integrates STEM (science, technology, engineering, and mathematics) will improve students' conceptual understanding of physics. The STEM approach is a learning approach that aims to improve students' knowledge and skills as a whole. Research has been conducted to improve conceptual understanding and scientific literacy on Newton's Law through

STEM-integrated inquiry-based learning [23]. The research findings show that students' conceptual understanding is better with integrated STEM than with non-integrated STEM [23], [26].

Table 2. Results of Analysis of Articles that Meet Inclusion Criteria

Author, Year	Learning Model	Ability	Results
Rivai et al. (2018) [27]	Problem-Based STEM	Concept Mastery	The research found that problem-based STEM learning improved students' understanding of dynamic fluid concepts. This can be seen from the increase in concept mastery scores from the pretest to the posttest. Students also showed improvement in describing and applying physics concepts related to dynamic fluid after problem-based STEM learning. In conclusion, this learning method has a significant positive impact on students' understanding of the material.
Nurbaya et al. (2019) [28]	STEM-Based Inquiry Learning	Concept Mastery	The results show that inquiry learning in STEM effectively improves students' concept mastery. Students' ability to apply the principle of continuity and Bernoulli's law together becomes better. The improvement of students' concept mastery is characterized by the increasing number of students who shift their answers from answers that use naive thinking to answers that provide logical and scientific explanations by the problem.
Nisa et al. (2020) [29]	Guided Inquiry Assisted STEM-Integrated Module	Concept Mastery	Guided inquiry learning with STEM module directs students to use physics principles to solve real problems. The module guides students in creating solutions to dynamic fluid problems in everyday life, integrating science, technology, engineering, and mathematics. It improves students' understanding of physics concepts, as evidenced by increased concept mastery and the strong effect size value. This approach can also be applied to other physics topics, helping students connect physics concepts holistically.
Parno et al. (2021) [30]	IBL (Inquiry-Based Learning)-STEM	Understanding Concept	Research shows that IBL-STEM learning with Formative Assessment significantly improves students' conceptual understanding of fluid dynamics (N-gain 0.63 and d-effect size 3.645). This setting makes students play the role of researchers, increasing their confidence and understanding. However, students still faced some difficulties with certain concepts, such as flow rate and the relationship between flow velocity, diameter and pressure. This research is limited to fluid dynamics material, and exploring the STREAM approach that includes religious and artistic aspects for Physics learning is recommended.
Parno et al. (2021) [31]	Experiential Learning-STEM	Concept Mastery	This study concluded that students' posttest scores were higher than the pretest, with a significant increase in concept mastery (high category N-gain). EL-STEM with Formative Assessment effectively builds mastery of fluid dynamics material, especially on the subtopics of Bernoulli's principle and Continuity, with higher effectiveness on Bernoulli's principle. Before learning, students had difficulty understanding almost all the material, but afterwards only struggled with some specific concepts. It is suggested to add religious and art aspects to the STREAM approach for other physics topics in the future.
Permana et al. (2021) [6]	IBL (Inquiry-Based Learning)-STEM	Creative Thinking Ability	Students' creative thinking skills improved significantly through IBL-STEM with Formative Assessment, with an N-gain of 0.64 (medium category) and d-effect of 5.05 (very large category). This method improved students' fluency, flexibility, originality and elaboration of thinking. Even so, after learning, students still have difficulty in flexibility in developing tools based on the Continuity Principle and environmentally friendly chimney design, as well as original thinking to determine the yield of high-speed spray.

Inquiry-based Learning (IBL) allows students to act as researchers. Students are given the freedom to find problems, make experiments, and show the results. IBL also gives students the freedom to create their own concepts. Students' creative skills can be enhanced with this freedom. Since the set of experiments does not correspond to the real world, other studies have shown that students are not interested in IBL. In contrast, research [6] advocates for STEM to be incorporated into IBL [32], [33].

4) Experiential Learning-STEM

The active involvement of students can manifest during observation and reflection processes. This is supported by the Experiential Learning model, which emphasizes direct and concrete experiences as the foundation for observation and reflection [34]. Two critical experiences for students in implementing innovative Experiential Learning are the design experience and the acceptance of concepts. Research indicates holistic learning can enhance students' conceptual understanding [35]. Furthermore, engaging in product engineering activities integrating science, technology, and mathematics within the STEM framework—a core aspect of Experiential Learning (EL)—enables students to develop critical thinking, problem-solving, creativity, and collaboration skills. These competencies, alongside conceptual mastery, are essential for meeting 21st-century learning demands [36]. Through the STEM approach, students can gain meaningful learning experiences [37], deepen their conceptual understanding, and collaborate in groups to apply their knowledge to real-world problem-solving [37], [38].

Improvement of Concept Mastery and Creative Thinking Ability with a STEM-Based Learning Model

Several studies have explored the impact of STEM-based learning models on students' mastery of dynamic fluid concepts, employing various methods and analyses. Research [27] analyzed quantitative data using the Wilcoxon Signed Rank Test, Normalized Gain Score, and Effect Size. The results revealed an Asymp. Sig. (2-tailed) value of $0.000 < 0.005$, a Normalized Gain Score of 0.58 (medium category), and an Effect Size of 1.44 (strong). These findings demonstrate that STEM problem-based learning significantly enhances students' understanding of dynamic fluid concepts.

Another study [29] investigated using Guided Inquiry learning with integrated STEM modules. The results showed a gain value (g) of 0.652, indicating improved students' conceptual understanding. Additionally, the effect size value of 4.49 was classified as strong, underscoring the effectiveness of this approach in reducing student misconceptions and enhancing physics concept comprehension.

Research [28] utilized pretest and posttest data analyzed through constant comparative techniques. The findings highlighted shifts in students' response categories for each item, suggesting that STEM-based inquiry learning effectively supports the mastery of dynamic fluid concepts.

In a study [30], data analysis employed the Wilcoxon Signed Rank Test, N-gain, d-effect size, and student answer descriptions. The findings indicated that IBL-STEM combined with Formative Assessment significantly improved students' understanding, with an N-gain value of 0.628 (medium category) and a d-effect size of 3.645 (very large category).

Similarly, the study [31] applied the Wilcoxon Signed Ranks Test, N-gain, and descriptive analysis of student answers. Results demonstrated that Experiential Learning-STEM with Formative Assessment effectively enhanced students' understanding of dynamic fluid topics, particularly the Bernoulli law, compared to continuity subtopics. While initial learning challenges spanned most dynamic fluid concepts, post-learning difficulties were limited to specific areas, such as understanding relationships in Bernoulli's law and designing effective airplane wings.

Finally, the study [6] combined quantitative analysis (Wilcoxon test, d-effect size, N-gain) with qualitative methods (coding, data reduction, and conclusion drawing). The intervention improved students' creative thinking, with an N-gain value of 0.64 (medium category) and a d-effect size 5.05 (very large category). Despite notable improvements, students faced flexible and original thinking challenges, such as designing tools based on continuity principles or creating effective, eco-friendly chimneys. These findings affirm the potential of IBL-STEM with Formative Assessment to enhance conceptual understanding and creative thinking in dynamic fluid learning.

IV. Conclusions

This research, with the Systematic Literature Review (SLR) model with the PRISM method, aims to determine how STEM-based physics learning is implemented on dynamic fluid material. Based on the review conducted on 6 articles from Google Scholar, Journal of Physics: Conference Series, and AIP Conference Proceedings, overall, the literature states that the learning model integrated with STEM can improve students' measured abilities. The measured student abilities include concept mastery and creative thinking. The learning models integrated with STEM are problem-based learning, module-assisted inquiry learning, guided inquiry learning, and experiential learning.

This study has several limitations, including the number of articles analyzed is limited to only 6 articles, so the findings may not represent the entire literature related to STEM learning on dynamic fluid material. In addition, this study has not considered other factors, such as differences in student characteristics or educational contexts, that could affect the success of STEM learning models. For future research, expanding the scope of articles analyzed and involving various educational contexts is recommended. The research could also involve experiments or field studies to see how the STEM model is applied in more diverse situations and impacts students' concept mastery and creative skills.

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