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Exploring Research on the Development of Modern Physics Learning Tools: Conceptual Study

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Abstract

This article presents a conceptual study (literature review) of several research results focused on developing modern physics learning tools. The research subject comprises ten articles from national and international journal databases within the last ten years (2014-2024). The results of the conceptual study show that several studies have developed teaching materials for Modern Physics lectures, but they still have limitations. These limitations are that the scope of the modern physics material developed has yet to be efficient for students to use online; the teaching materials developed in the form of applications are quite heavy when opened using a smartphone and require quite a large storage space capacity. The use of multimedia in physics learning in Indonesia is quite rapid, easy to present material, efficient to use, and supported by the latest applications to produce teaching materials that can insert text, images, videos, and interactive quizzes. The conclusion obtained from this conceptual study research is that the development of modern physics learning tools has been proven to improve the quality of learning, and there has yet to be any development of modern physics teaching materials based on interactive multimedia. The results of this conceptual study became one of the bases for developing teaching materials for modern physics based on interactive flipbooks. Implications of research on curriculum development and modern physics improving students' critical thinking skills. This approach is expected to increase students' interest in studying modern physics.

Keywords: electronic textbooks; interactive flipbooks; learning multimedia; modern physics

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INTRODUCTION

The modern physics course is one of the mandatory courses in the physics education study program curriculum for Physics Education undergraduate students. Modern physics courses present revolutionary concepts, providing a theoretical basis and understanding of the development of physics concepts that emerged at the end of the 19th and early 20th centuries, different from classical Newtonian physics (Balta & Eryılmaz, 2020; Marisda et al., 2023a). Classical physics courses focus on direct observations of physical quantities and simple experiments, while modern physics requires a deep understanding of theories developed through advanced

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mathematics (Goddi et al., 2017; Marisda et al., 2023b), such as calculus, linear algebra, and differential equations. Modern physics also presents counterintuitive concepts; many concepts from modern physics do not match everyday intuition, such as time dilation and quantum superposition. Most of the content of contemporary physics is abstract and includes the study of microscopic phenomena.

The abstract nature of modern physics content makes it difficult for students to understand concepts in depth (Yuanita et al., 2015). One of the contents of modern physics dominated by abstract and microscopic concepts is the photoelectric effect, which examines Planck's constant in determining standards for measuring electricity and mass. Therefore, it requires technological assistance to insert images and animations to present material (Daruwati, 2020). The abstract nature of modern physics material gives students a long time to understand the lecture material delivered by the lecturers who teach the course (Michelini et al., 2014).

The goal of the modern physics course for prospective physics teacher students is to help them grasp fundamental concepts. (Aksakalli et al., 2021) teaches basic concepts of modern physics such as relativity, quantum mechanics, and particle physics; students can apply theory, apply modern physics theory in various real situations and problems; students are trained in developing analytical skills, developing analytical and problem-solving abilities using modern physics principles; and advanced preparation, preparing students for advanced courses and research in physics and related fields. Some applications of contemporary physics in technology and industry include cutting-edge technology, such as developing new materials, communications technology, and medicine. Modern physics concepts, including electronics, telecommunications, and energy, are also used in industrial relevance.

After reviewing the characteristics of modern physics courses and the urgency of learning modern physics for prospective physics teacher students, modern physics lectures, where most of the concepts are abstract, require an innovative and effective approach to learning. Some strategies and methods that can be used are conceptual and visualization approaches, project and experimental-based learning, active and collaborative learning, technology and digital resources, and multisensory approaches that integrate various senses in learning (Halim et al., 2020). The form of implementation of these learning strategies and methods in the classroom can be designed with interactive lectures on the basics of quantum mechanics, followed by small group discussions on the application of Heisenberg's uncertainty principle; computer simulations with the use of software such as PhET Interactive Simulations to illustrate virtual quantum experiments (Susilawati et al., 2022); provides a simple project assignment in which students make a presentation about the applications of special relativity in modern technology (Park et al., 2019); uses a virtual laboratory to simulate particle physics experiments, allowing students to observe particles under conditions that are difficult to achieve in a regular laboratory.

METHOD

The study used a literature review method, meaning that data and information were obtained by analyzing the literature relevant to the studied topic. This method analyzes various articles and published studies. The subjects of this study were articles in reputable international journals indexed by Scopus, Web of Science (WoS), and Education Resources Information Center (ERIC). The selection of these journals underlines

the importance of using credible and internationally recognized sources to maintain the quality of research.

Initially, 29 articles were collected as initial data, but after a selection process based on certain criteria, only ten articles were selected for further analysis. The inclusion criteria used in this selection included the relevance of the topic to the research objectives, the appropriate publication period, the type of research (for example, whether the article is a literature review, empirical research, or case study report), the credibility of the source (especially from a reputable journal), and the language of the publication that supports the researcher's understanding. On the other hand, articles that were irrelevant to the topic, published too long ago, were of low quality or were duplicates of other research were excluded from the analysis.

The researchers then analyzed ten articles from reputable international journals to explore the development of modern physics teaching materials. The literature research process involves several stages: topic identification, where the researcher determines the main focus of the literature review; literature search, which involves collecting articles from various relevant journal databases; and *literature selection and evaluation*, which is the process of selecting the most relevant and quality articles to be analyzed. *Information synthesis* combines and describes information from selected articles to produce comprehensive research findings. All stages of this literature research are explained in more detail in Figure 1, which is likely a flowchart or visualization of these processes, providing a clearer picture of the research steps.

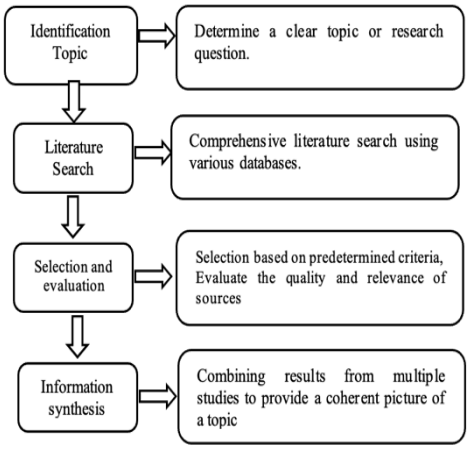

Figure 1 Stages of literature review

RESULT AND DISCUSSION

The articles included in the literature review were from 10 research journals. The research titles are described in Table 1 of the journal study related to modern physics lectures.

Table 1 Study of journals related to modern physics lectures

Year	Article Identity	Journal Review
2016	European Journal of Science and Mathematics Education, 4(1), 44-55.	Qualitative and quantitative research is needed to investigate the causes of students' negative perceptions of modern physics lectures. This research recommends the importance of pedagogical mastery for lecturers who teach courses and textbooks (teaching) that are appropriate to current developments and the physics curriculum (Aksakalli et al., 2021).
2017	Studies in Educational Research and Development, 1 (1).	Research that develops comics on black body radiation material (history of the discovery of Planck's opinion about black body radiation). The results of the research showed that students enjoyed the comics that were developed. However, students needed to provide meaningful opinions about the semi-historical content of the developed comic stories. The limitation of the research is that the material developed in the comic is still limited to the history of the discovery of Planck's opinion about black body radiation. Apart from that, no significant opinions were found from students after applying comics to learning modern physics (Ozdemir, 2017).

Year	Article Identity	Journal Review
2018	Journal of Physics: Conference Series 983 012052.	Research on website development to increase student interest in learning modern physics obtained a feasibility score of 3.72 for material, 3.25 for media, and 3.16 for user responses. The limitation of the research is that this design cannot be accessed freely via smartphone (Saehana et al., 2018).
2018	Journal of Physics: Conference Series, doi: 10.1088/1742-6596/1028/1/012205.	This research analyzes students' problem-solving abilities based on Polya's problem-solving steps. This research is initial research for developing learning models that can improve students' problem-solving abilities (Sartika & Humairah, 2018).
2020	The European Educational Researcher, doi: 10.31757/euer.313.	Research on the development of instruments to measure student learning achievement. The limitation of the research is that it was only carried out on a limited basis in Ankara, Türkiye (Balta & Eryılmaz, 2020).
2020	Conference Proceedings, doi: 10.2991/assehr.k.201230.063.	This research developed a digital book for learning modern physics whose validity has been tested by six experts. The validation results obtained an assessment percentage of 77.89% in the valid category, so it is suitable for use in modern physics learning (Saraswati et al., 2020).
2020	Journal of Physics: Conference Series, doi: 10.1088/1742-6596/1521/2/022004.	TEALSim is a pedagogical innovation in physics learning that utilizes multimedia in the form of interactive simulations through active learning. TEALSim is limited to wave-particle dualism physics material in one of the Physics Study Programs at PT in Makassar. This research is a quasi-experiment using two classes, one as a control class and another as an experimental class. This research provides information that there is a significant difference between the FCI test results of the experimental and control classes. At the same time, there is no significant difference in the MBT results of the two classes, so it is concluded that there is a need for other methods in using TEALSim to be able to improve conceptual, analytical and mathematical understanding (Swandi et al., 2020).
2022	Indonesian Review of Physics (iRip), 5(1), 8-15.	Research that develops photoelectric effect practical media based on Arduino Uno with Borg and Gall development stages. The research results show that the product's Planck constant is 6.62x10-34J.s. (Hamzah et al., 2022).
2022	International Journal of Emerging Technologies in Learning, 17(13), 267-277.	The research began with the problem of lecturers' difficulties in teaching abstract concepts in modern physics courses. Researchers applied digital technology by using virtual simulations integrated with the LMS platform. The digital technology applied is oriented towards a STEM learning approach. The results obtained are that virtual simulation learning has advantages compared to face-to-face methods that rely on expository teaching. This learning is limited to the concept of the photoelectric effect (Verawati et al., 2022).
2022	European Online Journal of Natural and Social Sciences, 11(4), 1166-1177.	This research develops multi-representation-based electronic books for hybrid learning. Two experts validated the resulting e-book and stated that it was suitable for use (Mulhayatiah et al., 2022).

Based on the findings of several previous studies, it can be assumed that several studies have developed teaching materials for modern physics courses, but they still have limitations. These limitations are in the scope of material development, which still needs to present modern physics material fully. The dominant modern physics material developed in previous research is the concept of relativity (Candido et al., 2022). Several previous studies have applied technology in developing modern physics teaching materials (Sun & Latora, 2020), but it still has limitations. This limitation is applying technology such as websites, computer-based modules (Rianti et al., 2020), and e-learning. This technology still requires students to access the application with a laptop or computer. Even though it can be accessed on several smartphones, the application is quite heavy when opened using a smartphone (Android/ios); apart from that, it also requires a large space capacity on the smartphone. These limitations certainly cannot accommodate students in independent study. Further research is recommended on developing modern physics teaching materials that focus on improving students' critical thinking skills. First, the development and testing of innovative teaching materials that utilize digital learning to enhance learning. Second, a comparative study of interdisciplinary approaches to enrich students' understanding. Third, the development of innovative curricula that integrate modern tools and inquiry methods. Fourth, research on improving students' critical and creative thinking skills. Fifth, a study of the long-term impact of using digital learning on learning outcomes, student interest, and improving critical thinking skills.

CONCLUSION

Based on the content analysis of journal articles, technology is necessary to develop modern physics lecture tools. However, interactive multimedia has not yet developed modern physics teaching material. The results of this conceptual study became one of the bases for developing teaching materials (in the form of electronic textbooks) for modern physics based on interactive flipbooks. Implications of research on curriculum development and modern physics improving students' critical thinking skills. This approach is expected to increase students' interest in studying modern physics.

However, this study has several limitations. One of them is the limited resources, such as funds and technological infrastructure, which can limit the implementation of modern digital-based physics teaching materials. Variability in technological capabilities across universities is also challenging, given that not all universities have the same access to sophisticated devices. Further research is needed to address these limitations and explore more inclusive and practical solutions.

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