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Literature Review on the Effectiveness of the 4D Model in Developing Science Learning Material

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Abstract: The 4D model (Define, Design, Develop, Disseminate) is a systematic approach widely used in the development of instructional materials, including in the field of Natural Sciences (IPA). This literature study aims to analyze the effectiveness of the 4D model in developing science learning materials across various levels of education. The study employs a literature review method by examining 40 scholarly articles discussing the implementation of the 4D model in science education contexts. The findings indicate that the 4D model is effective in producing science learning tools that are valid, practical, and effective in improving student learning outcomes, scientific thinking skills, and attitudes toward science. Each stage in the 4D model allows developers to systematically design and refine instructional materials based on student needs and the characteristics of science content. Additionally, the model is flexible and can be integrated with contextual approaches such as problem-based learning, inquiry-based learning, and STEM. Challenges in applying this model include limited development time and lack of teacher training. Therefore, institutional support and teacher capacity-building are essential factors in optimizing the model. This study recommends the 4D model as an effective framework for developing innovative and student-centered science learning materials aimed at enhancing scientific literacy.

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INTRODUCTION

Science is a subject that plays a crucial role in equipping students with the knowledge and skills to understand natural phenomena scientifically. The teaching of Natural Science aims not only to transfer knowledge but also to foster critical thinking, problem-solving abilities, and the development of a scientific attitude—essential for daily life and future endeavors. Thus, the quality of Natural Science instruction significantly influences the achievement of 21st-century competencies, which demand high scientific literacy (Yuliati, 2017). However, in practice, Natural Science education in schools often faces challenges, such as limited interactive learning media and a lack of teaching materials tailored to students' needs. This results in low student interest and poor learning outcomes in the subject. To address these challenges, innovative, effective, and student-centered teaching materials must be developed. Well-designed instructional

tools can enhance the teaching-learning process, improve student outcomes, and increase engagement with the subject matter. One proven approach for developing such materials is the use of instructional development models. A systematic development model is essential to ensure that the resulting materials are not only engaging but also possess content validity, practicality for classroom use, and effectiveness in achieving learning objectives (Nieveen, 2007).

One widely used model in educational research and material development is the 4D model (Define, Design, Develop, Disseminate), introduced by Thiagarajan, Semmel, and Semmel (1974). This model provides a systematic approach consisting of four key stages: the Define stage, which identifies student needs and characteristics while analyzing the curriculum; the Design stage, which drafts initial teaching materials; the Develop stage, which refines the product through validity and practicality testing; and the Disseminate stage, which implements the product on a broader scale. The strength of the 4D model lies in its ability to produce theoretically grounded teaching tools that are also tested and refined through validation and revision. Several studies have demonstrated that the 4D model yields adaptive teaching materials aligned with real-world classroom contexts (Trianto, 2010; Puspitasari & Suryadarma, 2021).

The 4D model facilitates a structured and iterative process wherein instructional materials are continuously refined based on expert evaluation and field-testing outcomes. This ensures not only theoretical rigor but also practical applicability in real classroom contexts (Sugiyono, 2015). Its adaptive nature empowers educators and developers to customize learning resources in accordance with student profiles and the shifting landscape of education. In the context of Indonesia's evolving educational framework, particularly under the Merdeka Belajar (Freedom in Learning) initiative, exploring and expanding the application of the 4D model is crucial—especially in the development of interactive and contextualized Natural Science teaching materials.

Aligned with the Merdeka Curriculum, which underscores personalized and student-centered pedagogies, the 4D model offers a relevant and responsive framework for designing instructional tools that address diverse learner needs. It enables teachers to promote meaningful learning experiences characterized by contextual engagement, interactivity, and learner autonomy (Kemendikbudristek, 2022). As such, instructional materials developed through this approach not only fulfill curricular mandates but also cultivate essential 21st-century competencies—including critical thinking, collaboration, and creativity (Trilling & Fadel, 2009).

Empirical studies support the efficacy of the 4D model in science education. For instance, Prihartini et al. (2015) reported that interactive multimedia developed using the 4D model significantly enhanced eighth-grade students' learning outcomes at SMP Negeri 7 Singaraja. Likewise, Fitriyati et al. (2016) found that 4D-based instructional materials effectively fostered students' scientific reasoning and higher-order thinking skills in junior high school settings. More recently, Surajuddin and Palennari (2024) developed a differentiated module on the human respiratory system using the 4D framework, demonstrating both its validity and practicality.

Nevertheless, the widespread adoption of the 4D model in Natural Science education faces several limitations, including restricted development time, insufficient resources, and a lack of comprehensive teacher training. Addressing these barriers is essential for optimizing its implementation. This study, therefore, aims to critically examine the effectiveness of the 4D model through a literature review approach, with the goal of offering evidence-based recommendations for educators and curriculum developers in the pursuit of innovative and impactful Natural Science teaching tools.

METHOD

This study is a literature review aimed at examining the effectiveness of the 4D model in developing instructional materials for science education. The research method involved collecting, reviewing, and analyzing a number of relevant scholarly articles from nationally accredited journals (SINTA) and reputable international journals indexed by Scopus. These articles specifically discuss the use of the 4D model in the context of developing science instructional

materials. The data collection process was carried out by searching for articles using keywords such as "4D model," "science instructional material development," "science learning media," and "4D model effectiveness." The searches were conducted through academic databases such as Google Scholar, DOAJ, Garuda, and ScienceDirect. To ensure the relevance to current educational developments, only articles published in the last five years (2019–2024) were selected. A total of 40 articles that met the inclusion criteria were analyzed qualitatively and descriptively. The inclusion criteria used in this literature review were as follows: (1) articles must discuss the application of the 4D model in the development of science instructional materials; (2) articles must be published in journals accredited by SINTA levels 1 to 3 or in reputable international journals; (3) articles must provide data related to the validity, practicality, or effectiveness of the developed instructional materials; and (4) articles must be written in either Indonesian or English.

The analysis of the collected data was conducted through several stages. First, data reduction was performed to extract the most relevant information from each article. Then, the findings were categorized based on the components of the 4D model (Define, Design, Develop, Disseminate), the types of instructional materials, the educational levels targeted, and the reported learning outcomes. These categorized findings were then presented in a descriptive narrative form to highlight the essential results of each study. Finally, conclusions were drawn through a synthesis of the strengths, weaknesses, and implementation potential of the 4D model in the context of science education.

This literature review method was chosen because it is suitable for exploring diverse research findings, identifying recurring patterns, evaluating effectiveness, and uncovering challenges in the application of the 4D model in developing science instructional materials.

RESULT AND DISCUSSION

The literature review reveals that the 4D model (Define, Design, Develop, Disseminate) is consistently used as an effective approach in developing science learning materials across different educational levels. The developed materials include teaching modules, interactive media, student worksheets (LKPD), and digital learning resources. In general, the application of the 4D model shows excellent results in three main aspects: validity, practicality, and effectiveness.

Validity of Learning Materials

Most studies report that learning materials developed using the 4D model are categorized as "highly valid" based on expert assessments. This high validity stems from the Define and Design stages, which enable developers to conduct needs analysis, identify learner characteristics, and formulate precise learning objectives. For example, Fitriyati et al. (2016) found that a 4D-based science LKPD was rated highly valid by subject and media experts, scoring above 85% on average.

Practicality of Implementation

The practicality of materials is evident from teacher and student responses to the implementation of the developed tools. In Prihartini et al. (2015), the developed science multimedia was found easy to use and helpful in explaining the respiratory system to students. This suggests that the Develop stage — which includes limited trials and revisions — plays a crucial role in refining the product before broader dissemination.

Effectiveness in Learning Outcomes

Many studies show that 4D-based science instructional materials positively impact students' learning outcomes. In the study by Surajuddin and Palennari (2024), students using 4D-developed modules showed a significant improvement from pre-test to post-test scores. This effectiveness is supported by visual media use, contextual approaches, and exploratory activities designed during the Design and Develop stages.

Challenges in Implementation

Despite its strengths, the literature also highlights several challenges in applying the 4D model, particularly during the Disseminate stage. This phase, which is crucial for ensuring that developed instructional materials are effectively implemented and evaluated, often encounters practical constraints in real-world settings. Among

the most commonly reported obstacles are limited resources, such as funding and materials, as well as time constraints faced by educators. Teachers are frequently burdened with administrative duties and teaching loads, leaving insufficient time to engage deeply with dissemination processes.

Furthermore, the literature notes that a lack of comprehensive training and support can hinder the proper execution of this stage. Many educators report difficulties in validating and refining instructional materials due to restricted access to subject-matter experts and standardized evaluation instruments. These limitations can compromise the quality and scalability of instructional innovations. Consequently, successful implementation of the 4D model necessitates institutional support, adequate training, and collaboration with experts to ensure that dissemination activities are both effective and sustainable.

Flexibility and Adaptability of the 4D Model

Another notable advantage of the 4D model is its flexibility to be integrated with active learning approaches such as problem-based learning, project-based learning, and STEM. A study by Widodo et al. (2021) demonstrated that 4D-based science materials integrated with STEM approaches significantly improved students' critical thinking skills.

CONCLUSIONS

Based on the literature review of various studies on the application of the 4D model in developing science learning materials, it can be concluded that the 4D model is an effective, systematic, and flexible approach. It produces learning tools that are valid, practical, and effective in improving learning outcomes, student engagement, scientific thinking skills, and science literacy. Each stage of the 4D model Define, Design, Develop, and Disseminate contributes significantly to the quality of the instructional products. The Define stage helps accurately identify learning needs, the Design stage facilitates structured and goal-aligned material planning, the Develop stage enables validation and revision, and the Disseminate stage allows for broader implementation to enhance educational impact. However, the model's implementation requires adequate resources, teacher training, and institutional support to function optimally. Common challenges such as limited development time, lack of technical training, and restricted access to validation experts must be addressed strategically. Therefore, the 4D model is strongly recommended as a framework for developing innovative and adaptive science instructional materials, particularly in support of 21st-century learning that emphasizes critical thinking, problem-solving, and contextual understanding. The model also holds strong potential for integration with approaches such as STEM and problem-based learning to create more holistic and meaningful learning experiences

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The authors declare no conflicts of interest.

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