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Review Article

A systematic literature review on the development of STEM-based module

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Abstract: Along with the growing awareness of the importance of STEM education, various research regarding STEM is increasingly being carried out. However, educators still have difficulty getting complete and comprehensive information regarding STEM modules that have been developed by researchers that can be applied in the classroom. The aim of this systematic literature review is to analyze papers that develop STEM-based modules with two review focuses, namely (1) the development model used; and (2) validation results of the modules that have been developed. The papers reviewed were limited to research published from 2019 using 2023 and accredited SINTA 2 and 3. Search results obtained 10 articles reporting the development of STEM-based modules. The most frequently used development model is ADDIE. This SLR provides a comprehensive analysis of the current trend of STEM education module development and be able to encourage future researchers to explore other aspects of STEM for research.

Keywords: module development; STEM-based learning; STEM Module

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1. Introduction

STEM education, which stands for Science, Technology, Engineering, and Mathematics, is a modern educational approach that emphasizes connections between scientific disciplines and problem-solving skills (Martín-Páez et al., 2019; Şahin, 2021; Xie et al., 2015). In line with students' need to master 21st Century skills, STEM education focuses on improving critical thinking, creative, collaborative and communication skills (Baran et al., 2021; Hacioğlu & Gülhan, 2021). STEM learning can not only increase students' science knowledge but also train them to apply the knowledge they learn in class to contextual problems (Sutaphan & Yuenyong, 2019). The application of STEM also encourages a student-centered-learning and active learning paradigm which will improve the quality of learning and student competence. Furthermore, the STEM approach is effective in difficult and complex science subjects (Çiftçi & Topçu, 2023). Based on research results, it shows that STEM learning can improve student learning outcomes (Óturai et al., 2023).

Modules are teaching materials that contain a set of planned learning experiences and are designed to achieve the expected competencies. Modules play an important role in learning because they provide a structured approach to activities and learning assessment. The development and evaluation of learning modules shows a significant increase in learning outcomes when compared to traditional learning (Houghton, 2023). The effectiveness of teaching modules can be taught in various aspects such as feasibility of content, linguistic components, assessment components, and graphic components (Marita et al., 2022). Furthermore, integrating an active learning approach with modules has a positive impact in increasing students' understanding of complex topics. Designing and

implementing well-structured modules will encourage interactive and effective learning experiences in various educational settings (Jacinto, 2022).

It is necessary to develop modules in accordance with developments in science and technology. One of the modules that has been developed is a STEM-based module. However, there are problems in the design and development of STEM learning. One issue is the source of STEM materials, or how STEM materials or modules are developed (Hsu et al., 2020). STEM research related to learning and the development of learning tools based on learning models has not been widely carried out (Parameswari et al., 2023).

Existing literature on STEM-based module has provided valuable insights into various aspects of the module development process. Several previous studies have explored various methodologies, development models, approaches, and frameworks for designing and implementing STEM-focused modules. For example, Murphy and Kelp (2023) research examines the influence of STEM learning on science communication skills, science identity, science self-efficacy and student motivation, while Hsu et al. (2020) examines the development of an Interdisciplinary Bio-Sensor STEM module for learning concepts and procedures. Additionally, Wang and Shen (2023) explored the development of a STEM affective learning measurement instrument, and Wieselmann et al. (2023) researched technology-enhanced collaborative learning in STEM. Despite the contributions of these studies, there is still a gap in the literature regarding the systematic comparison and evaluation of different research development models specifically designed for STEM module development. This highlights the need for further research to address this gap and provide guidance for educators and curriculum developers in the domain of STEM education. Based on the background, this paper will review and analyze several previous research articles to determine the suitability of STEM-based module teaching materials and the development model used in developing the module. In reviewing those articles, it is hoped that it can become a reference in developing teaching materials for the next module.

2. Materials and Methods

The method used in this paper is systematic literature review (SLR). Using SLR, this paper reviews various articles that report research with a research and development design whose development focus is STEM-based modules. The two research questions used in this SLR are: what development model is used by researchers in developing STEM-based modules? and what are the validation results of the module that has been developed?

Table 1. Inclusion and exclusion criteria

Inclusion	exclusion
Journal articles for the 2019 period-2013	Journal articles before 2019
Journal articles resulting from research	Duplicate journal articles
Full text journal articles	Journal articles are abstracts only

After formulating the research question, a search query used to collect the papers to be reviewed is formulated. Google Scholar was chosen as the database where papers were searched. Inclusion and exclusion criteria were also established before all papers were reviewed. The inclusion and exclusion criteria for this SLR are presented in Table 1.

The journals reviewed are those published from 2019 to 2023, articles accredited by Sinta 2 to Sinta 3. The data processing process for this research starts from collecting data related to the research title, then conducting data analysis in the form of elaborating a module development model and compare the module feasibility results from each related research journal.

3. Results

After searching for papers based on search queries and predetermined inclusion and exclusion criteria, 10 papers discussing the development of STEM-based modules were successfully collected and retained. Detailed information regarding the author's name, year of publication, development model, and findings from the ten papers is presented in Table 2. Based on Table 2, the development models used by the authors in developing the module are ADDIE, 4D, ASSURE, Rowntree, and Dick and Carey.

Table 2. Review results from 10 paper about STEM-based module development

No	Author and publication year	Method	Findings
1	Ferdiani and Pranyata (2022)	Miles and Huberman model	The results of this study are The assessment of experts obtained an average percentage of 87.9% (very valid), Small group test results of 92.6% (very feasible), Large group test results obtained 79.4% (effective). The mathematics teaching module of STEAM-based STEAM PjBL quantitative material has proven to be very valid, feasible and effective for improving the learning outcomes of students of SMK TKJ.
2	Almuharomah et al. (2019)	ADDIE	The STEM Physics module integrated with local wisdom "duck" to improve creative thinking skills is worthy of being used as a companion to textbooks in schools.
3	Agung et al. (2022)	4D	Based on the results of the research, the e-module has obtained a valid assessment in terms of material, language, and media and effectively improves student learning outcomes.
4	Marsitin and Sesanti (2022)	ADDIE	The results showed that the results of the response to the STEM-based mathematical statistics e-module were in accordance with student needs, namely: having ease, attractiveness and usefulness. The conclusion of the research results is that the STEM-based mathematical statistics e-module is declared valid, very effective and very feasible.
5	Sari et al. (2022)	4D	The data used in this study is quantitative obtained scores from

No	Author and publication year	Method	Findings
			validation sheets that obtain a final average percentage score of 83% with very feasible assessment criteria and qualitative data obtained from criticism, input, and suggestions from validators. The decision of the validator can be seen from the conclusions that have been filled in on the validation sheet. Of the 3 validators among them, 2 validators decided it was feasible with revisions and 1 validator decided it was feasible without revisions. So that revisions are carried out in accordance with validator suggestions and inputs to make e-modules in the criteria feasible.
6	Pixyoriza et al. (2022)	ADDIE	The quality of the digital modules developed is reviewed from the aspects of validity, practicality, and effectiveness. The result is that the digital module developed is included in the valid category with an overall percentage of 88.67%, and the practicality of the digital module is seen from the response of students with a percentage of 87% and the response of educators 83.90% with a very practical category. The effectiveness aspect based on the learning outcomes test with problem solving questions has increased in terms of pretest and posttest results with an N-gain of 0.69 medium category. Based on the results and analysis, it can be concluded that the digital modules developed are valid, practical, and effective and feasible for students to use in learning mathematics by students
7	Rizaldi et al. (2022)	Rowntree development model	Based on the results of expert validation, very valid content aspects were obtained with a score of 91.4%, very valid linguistic aspects with a score of

No	Author and publication year	Method	Findings
			97.1%, and very valid design aspects with a score of 94.2%. The practicality of this electronic module also received a score of 93.75% with a very practical category which was assessed through the one-to-one evaluation stage and through the small group evaluation stage with a score of 88.89% in the very practical category. The implication of this research is the availability of teaching materials that are in accordance with optical lectures for physics education students and support students in learning.
8	Jannah et al. (2021)	Dick and Carey	The results showed (1) The design of the I-STEM-based science module on Newton's Law material follows three steps from Dick and Carey's instructional design model, namely needs analysis, module development and module assessment. (2) The results of the assessment of experts, senior lecturers and science lecturers show that the I-STEM-based science module on Newton's law material is suitable for use in the science learning process in universities.
9	Oktaviani et al. (2020)	ADDIE	The results of the expert review stage obtained an average validity score of 0.90 on the Aiken scale with a high category. The results of the practicality test obtained an average score at the one-to-one stage of 0.93 and at the small group stage of 0.90 on the Aiken scale with a high category (practical). The results of the field test obtained an N-Gain value of 0.75 with a high category (effective). Based on the results of the evaluation, it shows that the resulting modules have met the criteria of valid, practical, and effective. It is suggested

No	Author and publication year	Method	Findings
			that this module can be used as an alternative teaching material in entrepreneurship courses.
10	Nurlatifah et al. (2023)	ASSURE	Based on validation by experts (material, language, and design) and respondents, the development of STEM-based science learning modules to improve the character of student curiosity is feasible to be used to facilitate educators and students in learning.

4. Discussion

The SLR reported in this paper informs that 50% of the papers reviewed use the ADDIE development model (Branch, 2009). This is because the development model is still very relevant to use and is able to adapt to various conditions where the ADDIE model can be applied with various models, methods, learning strategies, media and teaching materials (Rahmawati & Juandi, 2022). ADDIE is a systematic model for developing training that considers student needs and continuously collects feedback from target groups to ensure that training is designed effectively so that students achieve learning goals (Cotter et al., 2023). The ADDIE model provides systematic phases to guide instructors in generating ideas and developing teaching systems (Yu et al., 2021).

The SLR results show that 6 articles develop electronic modules while the other 4 develop printed modules. In relation to e-modules, e-learning is a transformative educational approach that combines learning with digital technology and the internet which revolutionizes learning styles and delivery of material (Daigavane, 2022; Jayanthi et al., 2023). This form of learning is in line with 21st Century developments because it optimizes students' digital skills. By implementing this kind of learning, it will empower students to adapt to the demands of the 21st Century, who are expected to become competent digital citizens and lifelong learners. Therefore, the large number of studies developing STEM-based e-modules indicates that some researchers are aware of the urgency of learning that is oriented towards the development of educational technology in the current era.

All modules reported are in the feasible category. Some have been implemented and some are only in development. Modules that have not been implemented or have not been tested in class due to time constraints, so researchers who use 4D only reach the 3D stage. The modules that have been implemented have been proven to increase students' curiosity, students' creative thinking abilities, problem-solving abilities and student learning outcomes. The findings reported by the authors are in line with research in other countries which also reports the influence of STEM learning on those student competencies (Baran et al., 2021; Hacioğlu & Gülhan, 2021; Martín-Páez et al., 2019; Şahin, 2021; Xie et al., 2015)

Based on the findings, STEM-based modules can improve student learning outcomes, one of which is problem solving. In accordance with research by Yeung et al. (2024), the implementation of STEM learning includes aspects of increasing engagement and interest in learning, as well as collaborative problem-solving abilities. Problem solving skills are very important in education which relate to complex situational cognition, behavior and attitudes in students (Amalina & Vidákovich, 2023). Problem solving skills are one of the cognitive activities that help students engage easily in practice and they are able to think using their rational capacity to develop and formulate appropriate solutions (Elaby et al., 2022). Based on the results of the review of this STEM-based development

article, it is hoped that it can provide new knowledge for teaching staff in developing modules that suit student needs.

5. Conclusions

This paper has carried out SLR on publications that report the development of STEM modules. Of the 10 papers that survived to the review stage, 50% used the ADDIE development model. Of the module types, 6 publications reported the development of electronic modules while the other 4 developed printed modules. Furthermore, the modules developed are feasible to use. Some studies do not implement the modules that have been developed, while other studies that have implemented the modules report their impact on students' curiosity, students' creative thinking abilities, problem solving abilities and student learning outcomes.

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