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Developing and Validating Digital E-module Oriented on Science Literacy using Flipbook Platform on Heat and Temperature Topic

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Abstract

This study explored the development and validation of a digital e-module for science literacy, specifically focusing on the topic of heat and temperature, utilizing the flipbook platform. With the rapid digitalization in education, the research aims to bridge the gap in Indonesia's educational technology, where many educators lack proficiency in using digital tools. The e-module, integrating multimedia elements such as text, images, and interactive features, is designed to enhance students' understanding of scientific concepts while fostering digital and science literacy. This study used Research and Development approach, utilizing the ADDIE model which includes five stages (analysis, design, development, implementation, and evaluation). The e-module underwent validation by experts in instructional materials and digital learning, followed by limited testing with 26 Grade 7 students and 4 science teachers. Results indicated that the digital e-module is not only feasible but achieved a content validity coefficient of 0.94 and an average practicality score of 87.63%, indicating high validity and practicality. The findings suggest that the e-module effectively supports science literacy by providing an engaging, accessible, and interactive learning experience. This study contributes to educational innovations by demonstrating how digital tools can enhance science teaching and learning, especially in the context of challenging topics such as heat and temperature. Further research may explore broader applications of e-modules in other subjects and educational levels.

Keywords: digital e-module; science literacy; heat and temperature topic; flipbook platform, ADDIE

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INTRODUCTION

The digital transformation in education has significantly altered the way learning takes place across the globe. In Indonesia, this shift has been instrumental in improving accessibility and efficiency within the educational sector (Amaliah et al., 2024; Ediyanto et al., 2021; Ghassani & Sugandi, 2023; Iskandar et al., 2023; OECD, 2024; Rabani et al., 2023; Rosyidah & Rindanigsih, 2024). Traditional learning methods have gradually been replaced with digital tools, allowing students to access information more easily and engage with content in diverse ways (Alanoğlu et al., 2021; Asif et al., 2022; Bismala & Manurung, 2021; Eslamian et al., 2023; Maqbool et al., 2022; Pham et al., 2019; Wawan Sudatha & Gede Agung, 2021; Zulkarnain & Herman, 2022). The integration of technology into education provides an array of benefits, such as flexible learning environments, the availability of multimedia resources, and improved teaching capabilities (Asratie et al., 2023; Briz-Ponce et al., 2017; Criollo-C et

al., 2021; Eshbayev & Nasiba, 2023; Faresta et al., 2024; Kumaidi et al., 2024; Stošić, 2015; Topalska, 2024).

According to recent studies, these digital tools also facilitate better engagement among students, particularly by incorporating various forms of media, such as images, videos, and interactive elements, which make learning more dynamic and interesting (Dervić et al., 2019; Marıkı, 2024; Teng, 2024; Κιουρεξίδου et al., 2024). Despite these benefits, however, the implementation of digital tools in the classroom faces challenges. One such challenge is the lack of proficiency among educators in using educational technologies effectively (Eskici & Çayak, 2023; Jobst et al., 2022; Shon et al., 2024; Wang et al., 2024). Based on some result study related, only 40.48% of Indonesian teachers are proficient in utilizing digital teaching tools, highlighting a need for better preparation and support for teachers in adopting technology in their classrooms (Ismail, 2023; Lindell, 2020; Meaney et al., 2023; Meirovitz et al., 2022; Rahman et al., 2015; Sismanto et al., 2024; Suwartono & Nitiasih, 2020). Furthermore, despite the vast potential of digital tools, their usage in Indonesian schools remains limited, particularly in terms of interactive and engaging teaching materials such as digital modules. Most prior digital tools have centered around static e-books, SCORM packages, or LMS-based content, which often lack contextualized science literacy components or full multimedia integration.

This research aims to address the gap in the availability of effective digital teaching tools by focusing on the development of an e-module designed to improve science literacy. While prior digital modules exist, none combine science literacy indicators with integrated multimedia using the flipbook format to target heat and temperature instruction specifically. In particular, the study aims to create an e-module that uses the flipbook platform to teach heat and temperature concepts. The flipbook format enables realistic page-flipping interaction, visual navigation, and seamless multimedia embedding, offering advantages over more rigid e-learning formats.

The heat and temperature topic in science is often seen as abstract and difficult for students to grasp, with students struggling to understand how temperature affects various physical phenomena (Abraham et al., 2021; Bada & Jita, 2023; Çetinkaya, 2016; Gürses et al., 2022; Haglund et al., 2015; Malík et al., 2019; Muliyani et al., 2023; Payu et al., 2023; Sukarmin et al., 2018). This issue is further exacerbated by the lack of resources that relate these concepts to real-life applications, which has been observed in numerous studies addressing the gap between theoretical knowledge and practical understanding in science education (Batlolona et al., 2020; Laius & Presmann, 2024; Luce & Callanan, 2020; Muliyani et al., 2023). Teachers often report that students have difficulty understanding how temperature and heat affect the world around them, leading to misconceptions and poor problem-solving abilities (Busyairi et al., 2022; Lubis et al., 2020; Septiyani & Nanto, 2021; Syefrinando et al., 2021; Vahit Işcan & Seyhan, 2021). The research problem is thus centered on improving students' understanding of these difficult concepts, making them more relatable, and fostering better science literacy (Haw et al., 2022; Ramdani et al., 2021; Setiawan et al., 2017; Sri Verawati et al., 2022; Sri Verawati & Sarjan, 2023; Wilson-Lopez et al., 2017).

The general solution proposed by the study involves the development of an interactive digital e-module based on the flipbook platform, which will provide students with a more engaging and flexible learning experience. This approach is grounded in the need for instructional materials that are more interactive and suited to the technological capabilities of today’s students. Previous research indicates that digital modules, when properly designed, have the potential to increase student engagement and motivation by integrating multimedia elements, which can improve understanding and retention of complex topics (Elisa et al., 2022; Li et al., 2024; Litna Tarigan et al., 2023; Noroozi & Mulder, 2016; Rahmawati et al., 2024). By using a digital flipbook, the study offers a more immersive learning experience that can potentially improve students' comprehension of the scientific principles behind heat and temperature, while simultaneously enhancing their digital literacy.

Specific solutions to the research problem can be found in the body of existing literature that explores the integration of digital modules in science education. For example, the use of electronic modules has been shown to provide an effective means of fostering engagement and promoting scientific understanding among students (Andriani et al., 2021; Astalini et al., 2019; Nababan et al., 2024; Nurmasyitah et al., 2023; Priambodo et al., 2023; Sintyah & Andromeda, 2024; Sugiarto et al., 2023). Moreover, integrating multimedia elements such as videos, animations, and interactive quizzes has been demonstrated to support the visualization of abstract scientific concepts and improve retention (Ayittey et al., 2019; He, 2023; Masitah et al., 2020; Nita et al., 2024; Nurhayati, Lasmawan, et al., 2022; Siahaan et al., 2024). Similarly, studies have shown that digital learning tools, such as the flipbook platform, have a unique capacity to simulate real-world environments while incorporating various media elements, thus providing a richer and more accessible learning experience (Astri et al., 2024; Erawati et al., 2024; Nurhayati, Linda, et al., 2022; Pitaloka et al., 2020). These previous findings suggest that a well-designed digital e-module, like the one proposed in this study, could effectively bridge the gap in students' understanding of challenging science topics (Chi et al., 2024; Kopeyev et al., 2020; Mouboua et al., 2024; Pierson et al., 2021; Williams & Benjamin, 2022).

Furthermore, there is a growing body of literature on the need for incorporating science literacy into education systems to ensure that students are prepared to tackle real-world problems and contribute to the advancement of society. Science literacy in this study refers to a multidimensional construct that includes understanding scientific content, applying it in real-life contexts, reasoning with evidence, and exhibiting attitudes such as curiosity and responsibility (Bajracharya et al., 2021; Norambuena-Meléndez et al., 2023). Science literacy refers to the ability to apply scientific knowledge to make informed decisions about natural phenomena and the impacts of human activity on the environment (Bajracharya et al., 2021; Heck et al., 2015; Norambuena-Meléndez et al., 2023; Summerell et al., 2015; Valladares, 2021). This is particularly important as the world faces increasing technological advancements and environmental challenges. Recent educational initiatives emphasize the importance of fostering science literacy in students through innovative teaching materials and approaches, such as the use of digital e-modules (Boudine et al., 2024; Dewi et al., 2022; Fadieny & Fauzi, 2021; Farooq et al., 2024; Nuraeni & Rosana, 2023; Rini & Cholifah, 2020; Verdugo Perona et al., 2015; Wahyuni, 2023; Weylin et al., 2023). This underscores the relevance of the current study, which aims to develop an e-module that not only teaches heat and temperature concepts but also enhances students' broader scientific literacy.

The literature reveals that while there have been many attempts to use digital platforms to teach science, there is still a gap in addressing the integration of digital tools into the everyday learning experiences of students, particularly in the context of Indonesian education. Existing studies have largely focused on the development of digital teaching resources in the form of e-books, videos, or standalone applications, without integrating the full potential of interactive multimedia tools (Harjono et al., 2020; Nielsen & Hoban, 2015; Putri et al., 2020; Utami et al., 2024). Additionally, while some studies have highlighted the importance of science literacy, there remains a lack of comprehensive solutions that effectively combine technology with the teaching of complex science topics such as heat and temperature (Amish & Jihan, 2023; Ariani et al., 2021; Azis & Cantafio, 2023; Winasti et al., 2019). This creates an opportunity for the present study to contribute new insights into the field of educational technology by exploring the use of a flipbook-based e-module as a comprehensive learning tool.

The primary aim of this study is to develop and validate an interactive e-module oriented towards science literacy, using the flipbook platform to teach the topic of heat and temperature. This study seeks to answer several key research questions: (1) What are the stages of developing a science literacy-oriented digital e-module on the topic of temperature and heat for seventh-grade science education? (2) What is the level of validity of the science literacy-

oriented digital e-module on the topic of temperature and heat for seventh-grade science education that has been developed? (3) What is the level of practicality of the science literacy-oriented digital e-module on the topic of temperature and heat for seventh-grade science education that has been developed? By addressing these questions, the study aims to provide valuable insights into the development and validation of interactive digital modules that can enhance both subject-specific knowledge and broader scientific literacy. Additionally, the study will contribute to the growing body of research on the use of digital tools in education, particularly in the context of science teaching in Indonesia.

METHOD

This study aims to develop and validate a digital e-module oriented towards science literacy, using the flipbook platform for teaching the topic of heat and temperature in secondary education. To achieve the research objectives, a systematic research methodology was employed, following a structured approach that ensured the validity and practicaly of the developed e-module. The methodology is organized into four key sections: research design, research subject, collection techniques and instrumental development, and data analysis techniques.

Research Design

The research design adopted for this study is a Research and Development (R&D) design, which is widely used for creating and testing new educational products or innovations (Molenda & Military, 2003). R&D design involves systematic steps to analyze, develop, implement, and evaluate educational materials. This study specifically uses the ADDIE model, which includes five phases: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model is commonly used in instructional design and provides a comprehensive framework for creating effective learning tools and materials.

In the analysis phase, the needs of the target group (students and teachers) were assessed to ensure that the digital e-module aligns with educational needs. The design phase involved structuring the e-module content and determining how multimedia elements would be integrated. The development phase focused on creating the e-module, while the implementation phase involved testing it with students. Finally, the evaluation phase assessed validity and practicality use of the e-module. This iterative approach allowed for continuous improvements and revisions to optimize the e-module's performance in teaching science concepts.

Research Subject

The research subject for this study consists of seventh-grade students in Indonesian secondary schools, particularly those enrolled in science courses. The study was conducted at a school in Makassar, Indonesia, specifically focusing on the topic of heat and temperature, which is known to be a challenging topic for students. Subject of research in thid study is 26 students of SMP Unismuh Makassar and 4 science teachers participated in the study. These students were selected based on their engagement with science subjects and their familiarity with digital learning tools.

Collection Techniques and Instrumental Development

The data collection techniques used in this study included questionnaires. The instruments used in this study were questionnaires for measuring practicality, and validation sheet for expert judgment. Each of these instruments was designed to gather data on different aspects of the study. Questionnaires were administered to both teachers and students to assess their opinions about content and practicality of e-module. The questionnaires contained Likert scale items that measured various factors, such as usability, engagement, and the clarity of instructional content.

Data Analysis Techniques

Data analysis for this study involved both qualitative and quantitative techniques to ensure a comprehensive evaluation of the e-module's validity and practicality. The data collected through questionnaires using descriptive statistical methods to summarize participants' responses. The analysis focused on measuring validity and practicality of the e-module in terms of student engagement, learning outcomes, and ease of use.

Descriptive Analysis

The quantitative data obtained from the questionnaires, were analyzed using descriptive statistics. This analysis provided insights into the overall validity and practicality of the e-module. Futhermore, the qualitative data were obtained from the analysis phase consisting of needs analysis, curriculum analysis, and student characteristics analysis, design phase, and development phase.

Validity

The content validity of the e-module was assessed through expert judgement. The e-module was reviewed by subject matter experts, instructional designers, and digital technology specialists. These experts provided feedback on the accuracy, clarity, and pedagogical soundness of the content. Table 1 presents the categories of validity for expert judgement, as determined through a Likert scale. The scoring system allows the experts to rate different aspects of the e-module, and the final validity category is determined based on the average score.

Table 1. Categories of Validity

Score	Category
4	Valid
3	Quite Valid
2	Not Valid
1	Invalid

The validity coefficien of the e-module was measured using the Gregory Content Validity Index (CVV) (Schraw & Moshman, 1995) using equation (1), which evaluated the agreement between expert raters on the relevance of the e-module's content. An index value of 0.90 or above was considered to indicate high content validity.

$$Content\ validity\ coefficient = \frac{D}{A + B + C + D} \quad \ldots (1)$$

Where A, B, C, and D represent the values in the contingency matrix, and the CVI represents the percentage of agreement between the two validators. A CVI value of 0.90 or higher indicates high content validity. Before determining the Gregory index, the strong and weak relevance assessments of the two validators are first carried out through a contingency table as shown in Table 2. Table 2 shows the contingency matrix used to calculate the Gregory Content Validity Index. This matrix allows for a comparison of the relevance ratings given by two validators for each item in the e-module.

Table 2. Contingency Matrix for Gregory Content Validity Index Calculation

Matrix 2x2		Validator 1	
		Not relevant (score 1-2)	Relevant (score 3-4)
Validator 2	Not relevant (score 1-2)	A	B
	Relevant (score 3-4)	C	D

Finally, Table 3 presents the levels of validity based on the calculated CVI. An index value above 0.90 is considered high validity, indicating that the e-module meets expert standards.

Table 3. Validity Levels Based on CVI

Coefficient	Validity Level
0.8 - 1.0	High Validity
0.4 - 0.79	Moderate Validity
0.00 - 0.39	Low Validity

Practicality Analysis

The practicality of the e-module was analysed using data from the questionnaires completed by both teachers and students. A Likert scale was used to assess the usability and overall satisfaction with the e-module. Data analysis for practicality was done by scoring the respondents' answers. The response questionnaire contained statements related to the problem-solving-oriented digital e-module that was developed. To calculate the percentage of each component, the following formula was used.

$$P = \frac{\sum x}{\sum xi} x100 \ldots (2)$$

Table 4 shows the practicality of the e-module, based on the scores provided by teachers and students. A score of 71% or higher indicates that the e-module is considered practical for classroom use. A score of 71% or higher was considered acceptable for the e-module to be categorized as practical for use in the classroom (Arikunto, 2014).

Table 4. Practicality Score

Score Range (%)	Category
25-50	Not Practical
51-70	Quite Practical
71-80	Practical
81-100	Highly Practical

RESULTS AND DISCUSSION

This chapter presents the results and discussion of the research, focusing on the development of a digital e-module for teaching heat and temperature. The findings are structured according to the main stages of the research process: Analysis, Design, and Development. Each stage provided insights into the process of creating the e-module, its effectiveness, and its practicality, supported by quantitative and qualitative data. The results are then discussed in relation to the research questions, literature, and theoretical framework.

Analysis phase

The analysis phase of the research focused on understanding the initial needs of both teachers and students to inform the development of the digital e-module. A comprehensive needs analysis was conducted, which included interviews with science teachers, questionnaires for students, and an evaluation of the curriculum. The goal was to identify the key challenges students face in understanding the concepts of heat and temperature and to determine how a digital e-module could address these challenges.

Need Analysis

The results of the initial study related to the mapping of students' science literacy skills using the science literacy test showed that 56% of students had low science literacy skills, 20% of students were in the medium category, and 24% of students were in the high category. This

finding shows that there is a need for maximum effort from educators and education observers in Indonesia in developing the science literacy skills of high school students.

The next needs analysis based on student responses related to the science subject teaching materials used by teachers shows that teachers only rely on printed books such as those currently distributed in several schools as the only teaching materials. The weakness of the textbook is that the material in the book still lacks contextual material that leads to the emergence of students' science literacy. In addition, the existing textbook material does not provide students with space to develop science literacy. Furthermore, the results of the student questionnaire analysis also showed that 60% of students had difficulty connecting science concepts, 53% of students had difficulty understanding the material, 87% of students felt uninterested in the presentation of the book material used, and 97% of students wanted books that were integrated with videos and easily accessible wherever and whenever students were. In terms of mastery of digital technology, around 90% of Unismuh Makassar Junior High School students have been able to and mastered the use of Android phones.

Based on these data, student readiness in using technology is considered adequate in the development of digital-based e-modules that will be accessed by students during learning. Further questionnaire analysis showed that students considered one of the science learning topics in grade VII of junior high school that was difficult for students to understand, namely the topic of Heat and Temperature. They stated that a number of concepts in this topic are abstract, closely related to students' daily lives, and difficult for students to understand. Due to the existing weaknesses, teaching materials are needed in the form of teaching modules that can facilitate the development of students' problem-solving abilities by utilizing digital technology that is fun for students in learning science.

Curriculum Analysis

The results of the curriculum analysis in the research school show that the material related to "Heat and Temperature" with indicators analyzing the effect of heat on changes in temperature and the state of objects in everyday life, as well as reporting the results of experiments on the effect of heat on objects is material that is considered difficult. This is because the concept of heat and temperature changes are abstract concepts for students so they have difficulty understanding how heat works and affects changes in the temperature of an object, students' limitations in relating the concept to everyday life due to lack of direct experience related to the topic, and difficulty identifying concrete examples in everyday life that illustrate the effect of heat on changes in temperature and the state of objects. This can be proven from the results of the student needs questionnaire that as many as 60% have difficulty in relating science concepts in everyday life and 53% have difficulty understanding the material if there are no examples.

Analysis of student characteristics

Most of the seventh grade students of SMP Unismuh Makassar have digital literacy skills. These characteristics include an understanding of the use of technological devices, navigation skills in digital platforms, and basic skills in utilizing online resources. This can be seen from the results of the needs analysis questionnaire where 26 seventh grade students of SMP in this case 100% stated that they could already use cellphones or cellphones to open Google, WhatsApp, YouTube, and other learning applications, and 83% of students wanted books that could connect to the internet, could play videos, and were more interesting than thematic books. Then the analysis of student characteristics related to learning styles is the process of understanding how each student best receives, processes, and remembers information.

Design

The design phase of the research focused on structuring the content of the e-module and determining how multimedia elements would be integrated to enhance student engagement and understanding. This phase involved e-module framework development stage, and e-module

design and feature development stage that would facilitate learning. The design was guided by the ADDIE model, which emphasizes the importance of aligning instructional goals with student needs and ensuring that the content is presented in an engaging and accessible manner.

E-module framework development stage

The development of the e-module framework, based on the science syllabus for seventh grade students in junior high school, follows a systematic and structured approach to ensure alignment with curriculum standards. The e-module is designed with three primary sections: the beginning, contents, and end.

According to previous research on instructional design, a well-organized framework that includes a clear introduction, structured learning materials, and a conclusion with practical applications enhances student engagement and learning outcomes (Mayer & Alexander, 2011). The beginning section includes essential elements such as a glossary, concept map, and basic competencies, providing students with a clear roadmap of the learning objectives and content (Alli et al., 2023; Ji et al., 2020; Licorish et al., 2018; Morrison et al., 2022; Osueke et al., 2018). The contents section, which focuses on the learning materials, is the core of the e-module, while the end section facilitates further learning through practice questions and independent assignments. This structure is consistent with best practices in digital learning design, which emphasize the importance of scaffolded learning experiences and opportunities for assessment (Rindengan & Rindengan, 2019; Widajati & Mahmudah, 2023; Zalavra et al., 2021).

E-module design and feature development stage

The e-module centers on five core components: a concept map that shows relationships among key ideas to guide learning (Figure 1); learning indicators and activities that state objectives and outline the tasks to achieve them (Figure 2); a science-facts section connecting temperature and heat to everyday contexts (Figure 3); a competency test to measure understanding of those concepts (Figure 4); and access via barcode/link (https://bit.ly/E-ModulSuhudanKalor)to open the full digital module on any device.

Figure 1. Map concept view

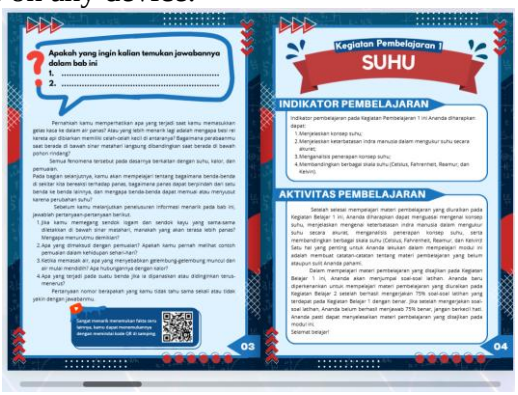

Figure 2. Learning indicators and activities view

Figure 3. Science fact view

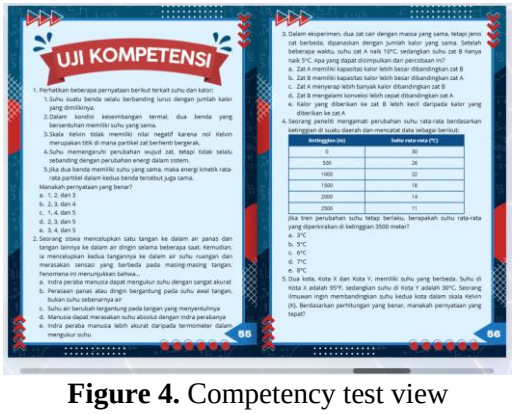

Figure 4. Competency test view

Development

The development phase involved creating the digital e-module based on the design specifications established in the previous phase. This phase included the production of multimedia content, programming interactive features, and ensuring that the module functioned properly on different devices. The development process was iterative, with feedback from both teachers and students being used to refine the e-module and make improvements.

Validation Results for Digital E-Module Teaching Materials

The tabulation results related to digital e-module teaching materials are shown in Table 5.

Table 5. Tabulation Results for Digital E-Module Teaching Materials

No	Aspect Assessment	Score average	
		V1	V2
1	Digital e-module display	3	4
2	Content of e-module teaching materials	4	4
3	Benefits of e-module teaching materials	4	4
4	Use of language	4	4

Table 5 shows that the aspect of the appearance of the digital e-module is at an average of 3 with a fairly valid category, the aspect of the content of the digital e-module is at an average of 4 with a valid category, the aspect of the benefits of the digital e-module is at an average of 4 with a valid category, and the aspect of the use of language in the digital e-module is at an average of 4 with a valid category. It can be concluded that the average acquisition of all aspects of the assessment from the two media experts is 4 with a valid category.

After obtaining the tabulation results from the material experts, the next step is to create a contingency table for the two experts. The contingency results of the two validators are shown in Table 6.

Table 6. Re-category contingency of two teaching material

Matrix 2x2		Validator 1	
		Not relevant	Relevan
Validator 2	Not relevant	0	1
	Relevan	0	17

Based on the contingency data from Table 5, the next step is to determine the validity coefficient using Gregory's content validity formula. The following is the determination of the content validity coefficient with the Gregory equation.

$$Content\ validity\ coeffisient = \frac{D}{A+B+C+D} = \frac{17}{0+1+0+17} = \frac{17}{18} = 0{,}94$$

The content validity coefficient, calculated using the Gregory formula, yielded a value of 0.94, which places the e-module in the 'high validity' category. This high coefficient (V = 94%) indicates strong agreement between the two validators, as values greater than 75% generally indicate a high degree of content validity (Herman et al., 1992). This finding supports the robustness of the e-module in achieving curriculum-aligned accuracy, clarity, and pedagogical soundness. A high content validity coefficient, like this one, suggests that the science literacy-oriented digital e-module aligns well with the intended curriculum and educational objectives. The e-module's content has been evaluated as both appropriate and relevant for its educational purpose, which is a critical factor in its potential effectiveness in enhancing students' science literacy (Popham, 2011, 1997). However, the process of enhancing content validity does not stop at the initial evaluation. Following expert feedback and revision of the e-module, the validity of the content was further strengthened. This iterative process, where revisions were made based on expert suggestions, crucial for ensuring that the educational material remains

up-to-date and pedagogically sound (Numata et al., 2020; Stiller et al., 2024; Tractenberg et al., 2024). Therefore, while the e-module currently demonstrates high validity, continual refinement through expert input will contribute to its long-term effectiveness in promoting science literacy.

Validation result of teaching material

The tabulation results to determine the assessments of the two experts can be seen in Table 7.

Table 7. Tabulation results from material experts

No	Aspect	Score average	
		V1	V2
1	Material relevance	4	4
2	Material organization	4	4
3	Effect on learning strategies	4	3
4	Sentence structure	3	4

Table 7 showed that the aspect of material relevance is at an average of 4 with a valid category, the aspect of material organization is at an average of 4 with a valid category, the aspect of the effect on learning strategies is at an average of 3 with a fairly valid category, and the aspect of sentence structure is at an average with a fairly valid category. Based on the data in Table 7, it can be concluded that the average acquisition of all aspects of the assessment from the two material experts is 4 with a valid category.

After obtaining the tabulation results from the material experts, the next step is to create a contingency table of two experts related to the assessment of the digital e-module material obtained through the provision of a questionnaire. Based on the results of the contingency table from the two experts, it shows that both validators stated that the material in the digital e-module is oriented towards solving problems from the results of the assessment of all aspects is in the value of 0.75 which is the agreement index of the two validators, it is stated that the validity is moderate. The category contingency of the two validators is shown in Table 8.

Table 8. Re-category contingency of two material experts

Matrix 2x2		Validator 1	
		Not relevant	Relevant
Validator 2	Not relevant	0	1
	Relevant	1	18

Table 8 shows that the ratings given by the two validators above can be calculated for validity based on Gregory's content validity formula as follows.

$$Content\ validity\ coeffisient = \frac{D}{A+B+C+D} = \frac{18}{A+1+1+18} = \frac{18}{20} = 0{,}90$$

The results of the material validation, with a content validity coefficient of 0.90, fall into the high validity category, demonstrating a 'high agreement' between the two validators (V > 75%). This outcome confirms that the material is valid, aligning with established standards for content validation (de Oliveira et al., 2024; Meijer et al., 2019; Varathan et al., 2023). Compared to similar studies such as Andriani et al. (2021) and Erawati et al. (2024), the module showed equivalent or stronger levels of content alignment and media integration. The high agreement suggests that the digital e-module content meet the expected educational requirements and suitable for its intended purpose in Science Literacy-oriented learning. The validators' recommendations to proceed to the next stage underscore the robustness of the material's content, confirming its readiness for practical implementation. As noted by Popham

(2011), a high validity coefficient is crucial in ensuring that educational materials meet the learning objectives effectively. The next step, focusing on the analysis of practicality, involves evaluating the e-module's usability based on teacher and student feedback. This evaluation is vital for determining how well the module supports real-world learning experiences and facilitates student engagement. The data on teacher and student responses are shown in Table 9.

Table 9. Results of teacher and student responses regarding the practicality of using digital e-modules

Respondent	Average Score (%)
Teachers	92, 75
Students	82,50
Average score	**87,63**
Category	**Highly practical**

Table 9 shows that the results from the evaluation of the practicality of using digital e-modules for Science Literacy-oriented science learning demonstrate highly positive feedback from both teachers and students. The average teacher response score of 92.75% falls within the 'very practical' category, suggesting that teachers found the e-modules to be an effective and efficient tool for science education. Similarly, the student response score of 82.50% also categorized as 'very practical,' further reinforces the e-module's utility in the classroom. The practicality of digital tools in education is essential for fostering an engaging and interactive learning environment (Henderson et al., 2015; Rashid & Asghar, 2016; Sun et al., 2017). The strong feedback from both groups indicates that the digital e-modules are not only user-friendly but also conducive to learning complex concepts such as Heat and Temperature. The positive reception aligns with previous studies that emphasize the importance of digital resources in enhancing science literacy by offering flexible, accessible, and engaging content (Popham, 2011). Students particularly noted the ease of navigation, responsiveness across devices, and the motivating role of video content, aligning with findings from Criollo-C et al. (2021) and Noroozi & Mulder (2016). This practical implementation of the digital e-modules thus supports the notion that such resources can be seamlessly integrated into the curriculum to improve students' understanding of scientific concepts. Moreover, it is crucial to continue evaluating these tools in real-world classroom settings to ensure their effectiveness and adaptability to diverse teaching and learning contexts (Asmianto et al., 2022; Maaruf et al., 2024; Nacaroğlu et al., 2025; Yadav, 2023).

CONCLUSION

This study developed and validated a digital e-module aimed at enhancing science literacy in students, specifically focusing on the challenging topic of heat and temperature. The results demonstrate that the e-module effectively addressed the challenges of abstract scientific concepts by incorporating multimedia elements, interactive features, and real-life applications that improved student engagement and understanding. The findings reveal that both students and teachers benefitted from the e-module, with students showing increased comprehension and interest in the topic. Teacher feedback also indicated that the e-module was an effective support tool for instructional delivery. The integration of videos, animations, quizzes, and simulations allowed students to interact with the content in a dynamic and flexible way, supporting independent learning. This study contributes to the growing body of research on the use of digital learning tools in science education, providing insights into how e-modules can be designed to meet the diverse needs of learners. It also reinforces the role of digital literacy in shaping science literacy outcomes. The study also highlights the importance of aligning educational materials with the curriculum while ensuring that they are accessible and engaging. This aligns with national educational goals that promote technology integration and inquiry-

based learning approaches. Furthermore, this research contributes to theoretical discourse by demonstrating how multimedia-supported modules can scaffold students' understanding based on constructivist learning theory and the development of science process skills.

RECOMMENDATION

Based on the findings of this study, it is recommended that further research be conducted to explore the broader implementation of digital e-modules in various science subjects. Future research could focus on expanding the scope of digital e-modules to other science topics, exploring the long-term impact of such tools on students' critical thinking and problem-solving abilities, and investigating how these tools can be adapted for different learning environments and educational systems. This may include both high-tech and low-tech classroom contexts. Also, future studies could investigate the adaptability of the e-module design to other topics beyond heat and temperature, assessing its impact on diverse scientific concepts and subjects. Additionally, research could focus on the long-term effects of using digital e-modules on student learning outcomes, particularly in terms of retention, problem-solving skills, and critical thinking. Tracking such outcomes over an academic semester or full year is encouraged.

It is also important to consider the integration of digital tools in classrooms with varying levels of technological infrastructure, as access to digital devices and the internet may be a barrier in some educational settings. Researchers should also address the potential challenges faced by educators in effectively incorporating digital e-modules into their teaching practices. This includes examining the role of teacher professional development and institutional support in successful integration. While the current study focused on the effectiveness of the e-module, further exploration of teachers' perspectives on its ease of use, their comfort with technology, and the necessary training required to use such tools will be essential in determining the sustainability of these tools in classrooms. Designing follow-up studies that include structured teacher training modules is highly encouraged. Finally, examining the scalability of digital e-modules across different educational systems and cultural contexts would be beneficial in ensuring their broader applicability and success in diverse settings. International comparative studies and multi-site implementation trials are suggested.

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REFERENCES

Abraham, Y. M., Valentin, M., Hansen, B., Bauman, L. C., & Robertson, A. D. (2021). *Exploring Student Conceptual Resources About Heat and Temperature*. https://doi.org/10.1119/perc.2021.pr.abraham

Alanoğlu, M., Aslan, S., & Karabatak, S. (2021). Do Teachers' Educational Philosophies Affect Their Digital Literacy? The Mediating Effect of Resistance to Change. *Education and Information Technologies*. https://doi.org/10.1007/s10639-021-10753-3

Alli, A., Renner, A. S., Kunze, K. L., Gross, J. J., Tollefson, S., Kuehntopp, M., Shah, A., Jordan, B., & Laughlin-Tommaso, S. K. (2023). Increasing Inclusion, Diversity, Antiracism, and Equity With a Medical School Curriculum Quality Improvement Project. *Journal for Healthcare Quality*. https://doi.org/10.1097/jhq.0000000000000373

Amaliah, A., Daleon Clorion, F. D., & Pasaribu, G. R. (2024). Importance of Mastering Teacher Pedagogical Competence in Improving the Quality of Education. *Pebsas*. https://doi.org/10.61721/pebsas.v2i1.346

Amish, M., & Jihan, S. (2023). Developing a Virtual Engineering Lab Using ADDIE Model. *Journal of E-Learning Research*. https://doi.org/10.33422/jelr.v2i1.417

Andriani, S., Masykuri, M., & Sukarmin, S. (2021). Pengembangan Elektronik Modul (E-Modul) Berbasis Guided Inquiry Pada Materi Suhu Dan Kalor Untuk Meningkatkan Literasi Sains Siswa Kelas Vii SMP/MTS. *Jurnal Penelitian Pendidikan Ipa*. https://doi.org/10.29303/jppipa.v7ispecialissue.1234

Ariani, R., Ratnawulan, R., & Fauzi, A. (2021). The Practicality of Interactive Multimedia Integrated Science Based on Guided Inquiry With Theme Energy in the Life That Integrates of Learning for the 21st Century. *Journal of Physics Conference Series*. https://doi.org/10.1088/1742-6596/1876/1/012051

Arikunto. (2014). *Evaluasi Program Pendidikan Edisikedua.* Bumi Aksara.

Asif, M., Khan, M. A., & Habib, S. (2022). Students' Perception Towards New Face of Education During This Unprecedented Phase of COVID-19 Outbreak: An Empirical Study of Higher Educational Institutions in Saudi Arabia. *European Journal of Investigation in Health Psychology and Education*. https://doi.org/10.3390/ejihpe12070061

Asmianto, A., Hafiizh, M., Rahmadani, D., Pusawidjayanti, K., & Wahyuningsih, S. (2022). Developing Android-Based Interactive E-Modules on Trigonometry to Enhance the Learning Motivation of Students. *International Journal of Interactive Mobile Technologies (Ijim)*. https://doi.org/10.3991/ijim.v16i02.27503

Asratie, M. G., Wale, B. D., & Aylet, Y. T. (2023). Effects of Using Educational Technology Tools to Enhance EFL Students' Speaking Performance. *Education and Information Technologies*. https://doi.org/10.1007/s10639-022-11562-y

Astalini, A., Darmaji, D., Kurniawan, W., Anwar, K., & Kurniawan, D. A. (2019). Effectivenes of Using E-Module and E-Assessment. *International Journal of Interactive Mobile Technologies (Ijim)*. https://doi.org/10.3991/ijim.v13i09.11016

Astri, Z., Noni, N., & Abd Halim, N. D. (2024). Integrating Digital Learning in English Reading Classes: Experiences of Indonesian Higher Education Lecturers. *Seltics Journal Scope of English Language Teaching Literature and Linguistics*. https://doi.org/10.46918/seltics.v7i1.2239

Ayittey, A., Arthur-Nyarko, E., & Onuman, F. (2019). Impact of Multimedia Instruction in Biology on Senior High School Students' Achievement. *Computer Science and Information Technology*. https://doi.org/10.13189/csit.2019.070502

Azis, I. R., & Cantafio, G. U. (2023). The Role of Virtual Reality in Science and Technology Education. *Jtest*. https://doi.org/10.51629/jtest.v1i1.170

Bada, A. A., & Jita, L. C. (2023). Effect of Brain-Based Teaching Strategy on Students' Retention and Self-Efficacy in Heat Energy. *Journal of Technology and Science Education*. https://doi.org/10.3926/jotse.1629

Bajracharya, B., Maden, U., Weiss, D., & Kucera, L. M. (2021). *Communicating Science for Informed Decision-Making*. https://doi.org/10.1007/978-3-030-73569-2_16

Batlolona, J. R., Singerin, S., & Diantoro, M. (2020). Influence of Problem Based Learning Model on Student Mental Models. *Jurnal Pendidikan Fisika Indonesia*. https://doi.org/10.15294/jpfi.v16i1.14253

Bismala, L., & Manurung, Y. H. (2021). Student Satisfaction in E-Learning Along the COVID-19 Pandemic With Importance Performance Analysis. *International Journal of Evaluation and Research in Education (Ijere)*. https://doi.org/10.11591/ijere.v10i3.21467

Boudine, H., Sajid, H., Bentaleb, M., Tayebi, M., & Karfa, D. El. (2024). M-Learning and Autonomous Education: The Impact of the Moroccan Digital Classroom Project on Science Subject's Learning. *Ijcsts*. https://doi.org/10.54878/1qcw9564

Briz-Ponce, L., Pereira, A., Carvalho, L., Juanes Méndez, J. A., & García-Peñalvo, F. J. (2017).

Learning With Mobile Technologies – Students' Behavior. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2016.05.027

Busyairi, A., Munandar, R., Dita Apsari, P. A., Wahyuni, A., Nurhasanah, N., Arni, K. J., Walihah, Z., & Diarta, M. H. (2022). Identification of Prospective Physics Teacher's Misconceptions of Temperature and Heat Concept Using the Three Tier Test. *Amplitudo Journal of Science \& Technology Innovation*. https://doi.org/10.56566/amplitudo.v1i2.9

Çetinkaya, M. (2016). Design of Personalized Blended Learning Environments Based on Web-Assisted Modelling in Science Education. *International Journal of Evaluation and Research in Education (Ijere)*. https://doi.org/10.11591/ijere.v5i4.5960

Chi, E., Cao, Y., Chen, Y., Wu, J., Oh, J., Deng, S., & Lau, N. (2024). K-12 Outreach: Experiential Learning in Human Factors With Laparoscopic Surgery Trainer Box. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. https://doi.org/10.1177/10711813241260748

Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2021). Mobile Learning Technologies for Education: Benefits and Pending Issues. *Applied Sciences*. https://doi.org/10.3390/app11094111

de Oliveira, D. A., Ferreira, D. D., Lisboa, L. L., & Xavier Nobre, T. T. (2024). Preparation and Validation of the Content of an Instrument to Assess the Quality of Services of Reception With Risk Classification in Obstetrics. *Plos One*. https://doi.org/10.1371/journal.pone.0315816

Dervić, D., Đapo, N., Mešić, V., & Đokić, R. (2019). Cognitive Load in Multimedia Learning: An Example From Teaching About Lenses. *Journal of Education in Science Environment and Health*. https://doi.org/10.21891/jeseh.481698

Dewi, C. A., Awaliyah, N., Fitriana, N., Darmayani, S., Nasrullah, N., Setiawan, J., & Irwanto, I. (2022). Using Android-Based E-Module to Improve Students' Digital Literacy on Chemical Bonding. *International Journal of Interactive Mobile Technologies (Ijim)*. https://doi.org/10.3991/ijim.v16i22.34151

Ediyanto, E., Kawai, N., Hayashida, M., Matsumiya, N., Bakor Siddik, M. A., & Almutairi, A. (2021). Indonesian Teachers' Attitudes Toward Inclusive Education. *Discourse and Communication for Sustainable Education*. https://doi.org/10.2478/dcse-2021-0014

Elisa, E., Prabandari, A. M., Istighfarini, E. T., Alivia, H., Inayati H, L. W., & Nuraini, L. (2022). Digital Module Innovation Based on Exploration of Physics Concepts Containing Local Wisdom "Making Traditional Snacks" to Support the Formation of Pancasila Students. *Jurnal Penelitian Pendidikan Ipa*. https://doi.org/10.29303/jppipa.v8i6.2171

Erawati, K. N., Dita Ardiani, N. N., & Santiago, G. A. (2024). E-Module Interaktif Berbasis Flipbook Pada Matakuliah Machine Learning Untuk Meningkatkan Kreatifitas Mahasiswa. *Jurnal Penjaminan Mutu*. https://doi.org/10.25078/jpm.v10i01.3603

Eshbayev, O., & Nasiba, M. (2023). Innovating Higher Education by Using Education Technology and Expert Systems: Pathways to Educational Innovation. *International Journal of Social Science Research and Review*. https://doi.org/10.47814/ijssrr.v6i6.1217

Eskici, M., & Çayak, S. (2023). The Relationship Between Teachers' Technology Proficiencies and Their Levels of Integrating Technology Into Their Lessons. *Journal of Educational Technology and Online Learning*. https://doi.org/10.31681/jetol.1331971

Eslamian, G., Khoshnoodifar, M., & Malek, S. (2023). Students' Perception of E-Learning During the Covid-19 Pandemic: A Survey Study of Iranian Nutrition Science Students. *BMC Medical Education*. https://doi.org/10.1186/s12909-023-04585-7

Fadieny, N., & Fauzi, A. (2021). Usefulness of E-Module Based on Experiential Learning in Physics Learning. *International Journal of Progressive Sciences and Technologies*. https://doi.org/10.52155/ijpsat.v25.1.2783

Faresta, R. A., Ser Nicholas, T. Z., Chi, Y., Natalia Sinambela, I. A., & Mopoliu, A. Z. (2024).

Utilization of Technology in Physics Education: A Literature Review and Implications for the Future Physics Learning. *Lensa Jurnal Kependidikan Fisika*. https://doi.org/10.33394/j-lkf.v12i1.11676

Farooq, E., Zaidi, E., & Ali Shah, M. M. (2024). The Future Classroom: Analyzing the Integration and Impact of Digital Technologies in Science Education. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan E-Saintika*. https://doi.org/10.36312/esaintika.v8i2.1957

Ghassani, N., & Sugandi, B. (2023). Professional Development Through Web-Based Training in Indonesia. *Jurnal Syntax Transformation*. https://doi.org/10.46799/jst.v4i2.690

Gürses, A., Şahin, E., & Güneş, K. (2022). Investigation of the Effectiveness of the Problem-Based Learning (PBL) Model in Teaching the Concepts of "Heat, Temperature and Pressure" and the Effects of the Activities on the Development of Scientific Process Skills. *Education Quarterly Reviews*. https://doi.org/10.31014/aior.1993.05.02.469

Haglund, J., Jeppsson, F., & Schönborn, K. (2015). Taking on the Heat—a Narrative Account of How Infrared Cameras Invite Instant Inquiry. *Research in Science Education*. https://doi.org/10.1007/s11165-015-9476-8

Harjono, A., Gunawan, G., Adawiyah, R., & Herayanti, L. (2020). An Interactive E-Book for Physics to Improve Students' Conceptual Mastery. *International Journal of Emerging Technologies in Learning (Ijet)*. https://doi.org/10.3991/ijet.v15i05.10967

Haw, L. H., Sharif, S., & K Han, C. G. (2022). Predictors of Student Engagement in Science Learning: The Role of Science Laboratory Learning Environment and Science Learning Motivation. *Asia Pacific Journal of Educators and Education*. https://doi.org/10.21315/apjee2022.37.2.11

He, Y. (2023). The Role of Rhythm in Science-Animated Videos: Construing Entities and Bridging Across Different Semiotic Modes. *Visual Communication*. https://doi.org/10.1177/14703572221112680

Heck, N., Stedman, R. C., & Gaden, M. (2015). The Integration of Social Science Information Into Great Lakes Fishery Management: Opportunities and Challenges. *Fisheries Research*. https://doi.org/10.1016/j.fishres.2015.01.008

Henderson, M., Selwyn, N., & Aston, R. (2015). What Works and Why? Student Perceptions of 'Useful' Digital Technology in University Teaching and Learning. *Studies in Higher Education*. https://doi.org/10.1080/03075079.2015.1007946

Herman, J. L., Aschbacher, P. R., & Winters, L. (1992). *A Practical Guide to Alternative Assessment*. https://doi.org/10.1007/s13398-014-0173-7.2

Iskandar, D., Rahayu, I., Ulum, U. A., Hakim, L., & Ruhiya, Y. (2023). The Utilization of 3D Technology in Mathematics Learning. *Jurnal Penelitian Pendidikan Ipa*. https://doi.org/10.29303/jppipa.v9i8.4284

Ismail, H. H. (2023). Using Digital Tools in Teaching and Learning English: Delving Into English Language Teachers' Perspectives. *Creative Education*. https://doi.org/10.4236/ce.2023.1410129

Ji, T. A., Wells, N., & Ingledew, P. (2020). Hand It to Dr Google: The Quality of Online Information on Ganglion Cysts. *Hand*. https://doi.org/10.1177/1558944719895780

Jobst, S., Lindwedel, U., Marx, H., Pazouki, R., Ziegler, S., König, P., Kugler, C., & Feuchtinger, J. (2022). Competencies and Needs of Nurse Educators and Clinical Mentors for Teaching in the Digital Age – A Multi-Institutional, Cross-Sectional Study. *BMC Nursing*. https://doi.org/10.1186/s12912-022-01018-6

Kopeyev, Z., Mubarakov, A., Kultan, J., Aimicheva, G., & Tuyakov, Y. (2020). Using a Personalized Learning Style and Google Classroom Technology to Bridge the Knowledge Gap on Computer Science. *International Journal of Emerging Technologies in Learning (Ijet)*. https://doi.org/10.3991/ijet.v15i02.11602

Kumaidi, M., Febriani, E., & Aisy, A. R. (2024). The Benefits of Technology in Islamic

Religious Education. *Education Achievement Journal of Science and Research*. https://doi.org/10.51178/jsr.v5i1.1811

Laius, A., & Presmann, M. (2024). The Pre-Service Teachers' Perceptions of Integrated Teaching, Inquiry Learning, Using ICT and Real-Life Examples in Science Classes. *Science Education International*. https://doi.org/10.33828/sei.v35.i2.3

Li, Y., Chen, D., & Deng, X. (2024). The Impact of Digital Educational Games on Student's Motivation for Learning: The Mediating Effect of Learning Engagement and the Moderating Effect of the Digital Environment. *Plos One*. https://doi.org/10.1371/journal.pone.0294350

Licorish, S. A., Owen, H., Daniel, B. K., & George, J. L. (2018). Students' Perception of Kahoot!'s Influence on Teaching and Learning. *Research and Practice in Technology Enhanced Learning*. https://doi.org/10.1186/s41039-018-0078-8

Lindell, T. L. (2020). Teachers Calling for Organizational Support to Digitalize Teaching. *International Journal of Information and Learning Technology*. https://doi.org/10.1108/ijilt-02-2020-0017

Litna Tarigan, W. P., Sipahutar, H., & Harahap, F. (2023). The Impact of an Interactive Digital Learning Module on Students' Academic Performance and Memory Retention. *Computers and Children*. https://doi.org/10.29333/cac/13654

Lubis, M., Sari, I. M., & Sinaga, P. (2020). *The Impact of Model Based Learning (MBL) in Improving Students' Understanding in Heat and Heat Transfer Concept*. https://doi.org/10.4108/eai.12-10-2019.2296488

Luce, M. R., & Callanan, M. A. (2020). Family Conversations About Heat and Temperature: Implications for Children's Learning. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2020.01718

Maaruf, S. Z., Fadzir, N. H., Izzati Rusli, N. S., Mohamad Nizar, N. N., & Wang, 王令宜 Ling-Yi. (2024). E-Rekad: Enhancing Students' Understanding of Visual Art Education in Malaysian Schools. *Environment-Behaviour Proceedings Journal*. https://doi.org/10.21834/e-bpj.v9i27.5339

Malík, A., Novita, Y., & Nuryantini, A. Y. (2019). Enhancing Critical Thinking Skills of Students Related to Temperature and Heat Topics Through Problem Solving- Laboratory Model. *Jurnal Penelitian \& Pengembangan Pendidikan Fisika*. https://doi.org/10.21009/1.05102

Maqbool, S., Farhan, M., Safian, H. A., Zulqarnain, I., Asif, H., Noor, Z., Yavari, M., Saeed, S., Abbas, K., Basit, J., & Ur Rehman, M. E. (2022). Student's Perception of E-Learning During COVID-19 Pandemic and Its Positive and Negative Learning Outcomes Among Medical Students: A Country-Wise Study Conducted in Pakistan and Iran. *Annals of Medicine and Surgery*. https://doi.org/10.1016/j.amsu.2022.104713

Marıkı, B. E. (2024). Multimedia Features Towards Skills Development in Open Learning: A Case of the Girls Inspire Project in Tanzania. *East African Journal of Education and Social Sciences*. https://doi.org/10.46606/eajess2024v05i05.0408

Masitah, R., Pamungkasari, E. P., & Suminah, S. (2020). The Effectiveness of Animation Video to Increase Adolescents' Nutritional Knowledge. *Media Gizi Indonesia*. https://doi.org/10.20473/mgi.v15i3.199-204

Mayer, R. E., & Alexander, P. a. (2011). *Handbook of Research on Learning*.

Meaney, T., Huru, H. L., & Kvivesen, M. (2023). Preservice and Inservice Teachers' Views on Digital Tools for Diverse Learners in Mathematics Education. *Nomad*. https://doi.org/10.7146/nomad.v28i3-4.149192

Meijer, H. A. W., Graafland, M., Obdeijn, M. C., Goslings, J. C., & Schijven, M. P. (2019). Face Validity and Content Validity of a Game for Distal Radius Fracture Rehabilitation. *Journal of Wrist Surgery*. https://doi.org/10.1055/s-0039-1688948

Meirovitz, T., Russak, S., & Zur, A. (2022). English as a Foreign Language Teachers'

Perceptions Regarding Their Pedagogical-Technological Knowledge and Its Implementation in Distance Learning During COVID-19. *Heliyon*. https://doi.org/10.1016/j.heliyon.2022.e09175

Molenda, H., & Military, B. (2003). *In Search of The Elusive ADDIE Model 5403107_71454778_Wk05_Molenda_ADDIEModel_PIJ2003*. *June*, 34–36.

Morrison, F. B., Raya, E. P., & Tarucan, P. R. (2022). Utilization of E-Learning in the Learning Activities in Higher Education. *International Journal of Science Education and Cultural Studies*. https://doi.org/10.58291/ijsecs.v1i2.47

Mouboua, P. D., Atobatele, F. A., & Akintayo, O. T. (2024). Bridging STEM and Linguistic Gaps: A Review of Multilingual Teaching Approaches in Science Education. *Open Access Research Journal of Multidisciplinary Studies*. https://doi.org/10.53022/oarjms.2024.7.2.0030

Muliyani, R., Suhandi, A., & Prima, E. C. (2023). Investigating Strategies and Best Practices in Teaching Heat and Temperature: A Systematic Review in Science and Physics Education. *Jurnal Penelitian Pendidikan Ipa*. https://doi.org/10.29303/jppipa.v9i7.4328

Nababan, R., Dharma, S., Siahaan, P. G., & Sihaloho, O. A. (2024). *Electronic Educational Module for Civic Education Based on the Cultural Values of North Sumatra Society*. https://doi.org/10.4108/eai.24-10-2023.2342354

Nacaroğlu, O., KIZKAPAN, O., & Demir, H. (2025). Middle School Students' Motivations and Learning Competencies in Science: Mediating Role of Digital Literacy. *Psychology in the Schools*. https://doi.org/10.1002/pits.23400

Nielsen, W., & Hoban, G. (2015). Designing a Digital Teaching Resource to Explain Phases of the Moon: A Case Study of Preservice Elementary Teachers Making a Slowmation. *Journal of Research in Science Teaching*. https://doi.org/10.1002/tea.21242

Nita, A. V., Kurniyanti, M. A., & Sulaksono, A. D. (2024). Effectiveness of Animation Video About Diabetes Mellitus Self-Care Management on the Level of Knowledge Among Elderly. *Health and Technology Journal (Htechj)*. https://doi.org/10.53713/htechj.v2i5.262

Norambuena-Meléndez, M., Guerrero, G., & González-Weil, C. (2023). What Is Meant by Scientific Literacy in the Curriculum? A Comparative Analysis Between Bolivia and Chile. *Cultural Studies of Science Education*. https://doi.org/10.1007/s11422-023-10190-3

Noroozi, O., & Mulder, M. (2016). Design and Evaluation of a Digital Module With Guided Peer Feedback for Student Learning Biotechnology and Molecular Life Sciences, Attitudinal Change, and Satisfaction. *Biochemistry and Molecular Biology Education*. https://doi.org/10.1002/bmb.20981

Numata, S., Nakataki, M., Hasegawa, N., Takaesu, Y., Takeshima, M., Onitsuka, T., Nakamura, T., Edagawa, R., Edo, H., Miura, K., Matsumoto, J., Yasui-Furukori, N., Kishimoto, T., Hori, H., Tsuboi, T., Yasuda, Y., Furihata, R., Muraoka, H., Ochi, S., … Hashimoto, R. (2020). *Improvements in the Degree of Understanding the Treatment Guidelines for Schizophrenia and Major Depressive Disorder in a Nationwide Dissemination and Implementation Study*. https://doi.org/10.21203/rs.3.rs-74919/v1

Nuraeni, A., & Rosana, D. (2023). The Development of E-Module Optical Physics Instruments Based on Creative Problem Solving (CPS) for Improving High School Students' Digital Literacy. *Joease*. https://doi.org/10.62672/joease.v1i2.17

Nurhayati, N., Lasmawan, I. W., Putu Arnyana, I. B., & Candiasa, I. M. (2022). Effectiveness of Animated Videos to Improve Science Process Skills and Creativity in Science Learning During COVID-19 Pandemic. *International Journal of Health Sciences*. https://doi.org/10.53730/ijhs.v6n2.8971

Nurhayati, N., Linda, R., & Anwar, L. (2022). E-Module Using FlipHTML5 Application on Chemical Bond Material. *Jurnal Pendidikan Kimia Indonesia*.

https://doi.org/10.23887/jpki.v6i2.49542
Nurmasyitah, Lubis, N. A., Saputra, H., & Derlina, D. (2023). Impact of Basic Physics E-Module Using Problem Oriented on Critical Thinking Skilss of Physics Teacher Candidate Student. *Jurnal Penelitian Pendidikan Ipa*. https://doi.org/10.29303/jppipa.v9i9.5002
OECD. (2024). *Transforming Education in Indonesia*. https://doi.org/10.1787/9ff8d407-en
Osueke, B., Mekonnen, B., & Stanton, J. D. (2018). How Undergraduate Science Students Use Learning Objectives to Study. *Journal of Microbiology and Biology Education*. https://doi.org/10.1128/jmbe.v19i2.1510
Payu, C. S., Hermanto, I. M., & Yunus, M. (2023). Validating an Innovative Guided Inquiry Learning Model for Critical Thinking in Temperature and Heat Concepts. *Jurnal Ilmiah Profesi Pendidikan*. https://doi.org/10.29303/jipp.v8i4.1835
Pham, L., Limbu, Y. B., Bui, T. K., Nguyen, H. T., & Pham, H. T. (2019). Does E-Learning Service Quality Influence E-Learning Student Satisfaction and Loyalty? Evidence From Vietnam. *International Journal of Educational Technology in Higher Education*. https://doi.org/10.1186/s41239-019-0136-3
Pierson, A. E., Clark, D. B., & Brady, C. (2021). Scientific Modeling and Translanguaging: A Multilingual and Multimodal Approach to Support Science Learning and Engagement. *Science Education*. https://doi.org/10.1002/sce.21622
Pitaloka, N. L., Anggraini, H. W., Kurniawan, D., Erlina, E., & Jaya, H. P. (2020). Blended Learning in a Reading Course: Undergraduate EFL Students' Perceptions and Experiences. *Indonesian Research Journal in Education |Irje|*. https://doi.org/10.22437/irje.v4i1.8790
Popham, W. . (2011). *Classroom Assessment What Teachers Need to Know* (7th ed.). Pearson.
Popham, W. J. (1997). *Whats-Wrong_and-Whats-Right_With-Rubrics*. Ebsco Publishing.
Priambodo, A., Kartiko, D. C., Al Ardha, M. A., & Rohman, M. F. (2023). Application of E-Module and Video Tutorials to Student Learning Motivation and Learning Effectiveness in Physical Education, Sports, and Health. *Juara Jurnal Olahraga*. https://doi.org/10.33222/juara.v8i1.2473
Putri, H. N. P. A., Wulandari, R. N., Fitriana, A., & Kusairi, S. (2020). The Comparison of High School Students' Understanding of Kinematic Materials: Case of Question Representations. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *9*(2), 241–249. https://doi.org/10.24042/jipfalbiruni.v9i2.6032
Rabani, S., Khairat, A., Guilin, X., & Jiao, D. (2023). The Role of Technology in Indonesian Education at Present. *J. Computer Science Advancements*. https://doi.org/10.55849/jsca.v1i1.403
Rahman, B., Abdurrahman, A., Kadaryanto, B., & Rusminto, N. E. (2015). Teacher-Based Scaffolding as a Teacher Professional Development Program in Indonesia. *Australian Journal of Teacher Education*. https://doi.org/10.14221/ajte.2015v40n11.4
Rahmawati, S., Nurhikmah, H., & Muin, A. (2024). Development of Web-Based Digital Mathematics Modules Grade VII SMPN 1 Watansoppeng. *Inovasi Kurikulum*. https://doi.org/10.17509/jik.v21i2.67846
Ramdani, A., Jufri, A. W., Gunawan, G., Fahrurrozi, M., & Yustiqvar, M. (2021). Analysis of Students' Critical Thinking Skills in Terms of Gender Using Science Teaching Materials Based on the 5E Learning Cycle Integrated With Local Wisdom. *Jurnal Pendidikan Ipa Indonesia*. https://doi.org/10.15294/jpii.v10i2.29956
Rashid, T., & Asghar, H. M. (2016). Technology Use, Self-Directed Learning, Student Engagement and Academic Performance: Examining the Interrelations. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2016.05.084
Rindengan, M. M., & Rindengan, M. E. (2019). *Scaffolding Model in Learning of Writing of Essays, Based on Experience*. https://doi.org/10.2991/icet-19.2019.56

Rini, T. A., & Cholifah, P. S. (2020). Electronic Module With Project Based Learning (PjBL): Innovation of Digital Learning Product on 4.0 Era. *Edcomtech Jurnal Kajian Teknologi Pendidikan*. https://doi.org/10.17977/um039v5i22020p155

Rosyidah, U., & Rindanigsih, I. (2024). Improving Teachers' Understanding of Inclusive Education. *Ijmi*. https://doi.org/10.61796/ijmi.v1i2.56

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, *7*(4), 351–371. https://doi.org/10.1007/BF02212307

Septiyani, E., & Nanto, D. (2021). Four-Tier Diagnostic Test Assisted Website for Identifies Misconceptions Heat and Temperature. *Jurnal Penelitian \& Pengembangan Pendidikan Fisika*. https://doi.org/10.21009/1.07104

Setiawan, B., Innatesari, D. K., Sabtiawan, W. B., & Sudarmin, S. (2017). The Development of Local Wisdom-Based Natural Science Module to Improve Science Literation of Students. *Jurnal Pendidikan Ipa Indonesia*. https://doi.org/10.15294/jpii.v6i1.9595

Shon, S., Shin, H., Rim, D., & Jeon, H. (2024). Nursing Faculty Development Program for Digital Teaching Competence. *BMC Medical Education*. https://doi.org/10.1186/s12909-024-05453-8

Siahaan, S. M., Patriot, E. A., Lestari, Y. I., Simarmata, R. H., Jannah, F. N., Nugraha, A., Hartati N, Y. T., Saparina Yuliani, E. N., Feranti, H., Putriani, A., & Husna, H. A. (2024). The Training and Assistance for Junior High School Science Teachers in Making Animated Videos Through Canva Application. *Unram Journal of Community Service*. https://doi.org/10.29303/ujcs.v5i4.736

Sintyah, D., & Andromeda, A. (2024). Validity and Practicality of Chemical Bonding E-Module Guided Inquiry Basef Integrated Virtual Laboratory for High School. *Edukimia*. https://doi.org/10.24036/ekj.v5.i3.a495

Sismanto, S., Cikusin, Y., & Mistar, J. (2024). Challenges and Strategies in Adopting Google Workspace for Education: Perspectives From Educational Leaders in Indonesia. *Asian Journal of Education and Social Studies*. https://doi.org/10.9734/ajess/2024/v50i41328

Sri Verawati, N. N., Handriani, L. S., & Prahanı, B. K. (2022). The Experimental Experience of Motion Kinematics in Biology Class Using PhET Virtual Simulation and Its Impact on Learning Outcomes. *International Journal of Essential Competencies in Education*. https://doi.org/10.36312/ijece.v1i1.729

Sri Verawati, N. N., & Sarjan, M. (2023). Challenges of Multidimensional Science Education: A Philosophical Perspective. *Jurnal Pijar Mipa*. https://doi.org/10.29303/jpm.v18i6.5701

Stiller, C., Brandt, L., Adams, M. A., & Gura, N. (2024). Improving the Readability of Patient Education Materials in Physical Therapy. *Cureus*. https://doi.org/10.7759/cureus.54525

Stošić, L. (2015). The Importance of Educational Technology in Teaching. *International Journal of Cognitive Research in Science Engineering and Education*. https://doi.org/10.23947/2334-8496-2015-3-1-111-114

Sugiarto, A., Sartika, R. P., HL, N. I., & Syarifuddin, S. (2023). Development of E-Module Using ROPES Strategy Assisted With Sigil Software to Improve Students' Critical Thinking Skills. *Jurnal Kependidikan Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan Pengajaran Dan Pembelajaran*. https://doi.org/10.33394/jk.v9i2.7527

Sukarmin, S., Ratnasari, D., & Suparmi, S. (2018). Profile Analysis of Students' Concept Understanding on Heat and Temperature. *Journal of Education and Learning (Edulearn)*. https://doi.org/10.11591/edulearn.v12i3.6427

Summerell, G., Littleboy, K., & Jenkins, M. (2015). *Customer-Focused Science for Environmental Sustainability: A Continuing Case Study From the NSW Government*. https://doi.org/10.36334/modsim.2015.k11.summerell

Sun, Z., Lin, C., Wu, M., Zhou, J., & Luo, L. (2017). A Tale of Two Communication Tools:

Discussion-forum and Mobile Instant-messaging Apps in Collaborative Learning. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.12571

Suwartono, T., & Nitiasih, P. K. (2020). ProDev Participation and Teaching Performance: A Case Study of Two Urban School EFL Teachers in Indonesia. *Universal Journal of Educational Research*. https://doi.org/10.13189/ujer.2020.080752

Syefrinando, B., Wirman, R. P., Basuki, F. R., & Andriani, N. (2021). The Effects of Generative Learning Model for Learning Temperature and Heat on Science Learning Outcomes. *Scientiae Educatia*. https://doi.org/10.24235/sc.educatia.v10i2.9093

Teng, P.-S. (2024). Gender Differences in Immersive Reading With Interactive Electronic Picture Books. *Tem Journal*. https://doi.org/10.18421/tem134-52

Topalska, R. (2024). A Research on the Application of Modern Information Technologies in Teaching. *Tem Journal*. https://doi.org/10.18421/tem133-27

Tractenberg, R. E., Moore, D., Clark, N., Lee, A., Bluman, J., Dykhuis, E. M., Nelson, R., Powell, M., Paynter, J. L., Grymes, J., Crofford, I. L., Lindquist, J. M., & Scioletti, M. (2024). *Integration, Not Concatenation (InC): Hacking Educational Materials to Facilitate Efficient, Effective, and Evaluable New Coverage*. https://doi.org/10.31235/osf.io/dx5vm

Utami, P. L., Hariyono, E., Hidaayatullaah, H. N., & Suprapto, N. (2024). Optimizing the Ferris Wheel Physics E-Book With Video Tracking Method to Enhance Student Learning Motivation. *Journal of Physics Conference Series*. https://doi.org/10.1088/1742-6596/2900/1/012033

Vahit Işcan, Y. V., & Seyhan, H. G. (2021). The Effect of the 5E Learning Model Supported With Material Ensuring Conceptual Change on Science Achievement: The Example of "Heat and Temperature." *Mimbar Sekolah Dasar*. https://doi.org/10.53400/mimbar-sd.v8i3.33044

Valladares, L. (2021). Scientific Literacy and Social Transformation. *Science \& Education*. https://doi.org/10.1007/s11191-021-00205-2

Varathan, K., Kumar, V. K. C., Subramanian, S. S., Alfawaz, S. S., Alzahrani, G. A., Sriraghunath, S., Priya, H., Senthil, P., Eswaramoorthi, V., & Mustafa Gaowgzeh, R. A. (2023). Validation of the Exercise Protocol Satisfaction Questionnaire by Content Validation Method. *Fiz Pol*. https://doi.org/10.56984/8zg20ad8a

Verdugo Perona, J. J., Solaz Portolés, J. J., & López, V. S. (2015). Is Digital Literacy Improving Science Education? *The New Educational Review*. https://doi.org/10.15804/tner.2015.40.2.13

Wahyuni, A. (2023). Development of Geogebra-Based Interactive E-Modules to Improve Students' Digital Literacy Abilities. *Ijasse*. https://doi.org/10.59890/ijasse.v1i4.1120

Wang, W., Wan, Q., Cui, J., & Liu, L. (2024). The Impact of Technological Innovation and Digital Arts Development on Chinese Guangdong Higher Vocational Education: A Theoretical Model and Empirical Analysis. *Tebmr*. https://doi.org/10.62051/hg27d451

Wawan Sudatha, I. G., & Gede Agung, A. A. (2021). *Implementation of Project-Based E-Learning in Courses Description Statistics During Covid-19*. https://doi.org/10.2991/assehr.k.211222.024

Weylin, Raharjo, H., Haqq, A. A., & Larsari, V. N. (2023). Empowering Students in the Digital Era: An Analysis of Interactive E-Modules' Effect on Digital Mathematical Communication. *International Journal of Mathematics and Mathematics Education*. https://doi.org/10.56855/ijmme.v1i02.401

Widajati, W., & Mahmudah, S. (2023). Technological Pedagogical Content Knowledge (TPACK) and Digital E-Scaffolding for Special School Teachers. *Studies in Learning and Teaching*. https://doi.org/10.46627/silet.v4i2.268

Williams, N., & Benjamin, A. (2022). An Investigation of Students' Views on Decolonising the Science Curriculum. *Compass Journal of Learning and Teaching*.

https://doi.org/10.21100/compass.v15i1.1258

Wilson-Lopez, A., Sias, C., Smithee, A., & Hasbún, I. (2017). Forms of Science Capital Mobilized in Adolescents' Engineering Projects. *Journal of Research in Science Teaching*. https://doi.org/10.1002/tea.21418

Winasti, S., Soetisna, U., & Hindriana, A. F. (2019). Pembelajaran Berbasis Multimedia Interaktif Untuk Meningkatkan Literasi Sains Dan Teknologi. *Edubiologica Jurnal Penelitian Ilmu Dan Pendidikan Biologi*. https://doi.org/10.25134/edubiologica.v6i2.2373

Yadav, R. P. (2023). Effects of Digital Resources in Science Teaching and Learning in Secondary Schools: A Study in Siraha District. *Orchid Academia Siraha*. https://doi.org/10.3126/oas.v2i1.65620

Zalavra, E., Papanikolaou, K., Dimitriadis, Y., & Sgouropoulou, C. (2021). *Exploring Teachers' Needs for Guidance While Designing for Technology-Enhanced Learning With Digital Tools*. https://doi.org/10.1007/978-3-030-86436-1_35

Zulkarnain, R., & Herman, H. (2022). Analysis of Content Benefits of Audiovisual Learning Models for Nonformal Early Children and Basic Education. *Devotion Journal of Research and Community Service*. https://doi.org/10.36418/dev.v3i14.305

Κιουρεξίδου, M., Kanavos, A., Klouvidaki, M. I., & Αντωνόπουλος, N. (2024). Exploring the Role of User Experience and Interface Design Communication in Augmented Reality for Education. *Multimodal Technologies and Interaction*. https://doi.org/10.3390/mti8060043