HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

August 2025. 13(4)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 752-765

Validity of the Corporate Edition Flip PDF Assisted Learning E-Module for Improving Students' Critical Thinking Skills

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Article History
Received: 06-07-2025
Revised: 29-08-2025
Published: 03-09-2025

Keywords: learning e-module; critical thinking; Flip PDF Corporate Edition; thermochemistry

Abstract
The rapid development of 21st-century technology demands that students possess critical thinking skills as one of their core competencies. To support the achievement of this competency, innovative, interactive, and relevant learning media are needed. This research is a Research and Development (R&D) study that aims to develop and test the content and construct validity of a Problem-Based Learning (PBL)-based e-module on Thermochemistry material, assisted by Flip PDF Corporate Edition. The development model used is 4D (Define, Design, Develop, Disseminate), but this research is limited to the develop stage. The main focus of the research lies in the validity aspects of the e-module, both in terms of content and construct, covering aspects of content suitability, language, presentation, and graphics. The instrument used was a validation sheet, assessed by three expert validators in chemistry education and instructional material development. The validation results indicate that the e-module is in the valid category, with a modal score of 4, which falls into the good category. This validation process was conducted to ensure that the developed e-module meets the feasibility standards as an interactive learning medium capable of fostering students' critical thinking skills. The findings from this validation stage will then serve as the basis for refining the e-module before it is piloted on a limited number of students.

How to Cite: Imara, S. Y., & Rusmini. (2025). Validity of the Corporate Edition Flip PDF Assisted Learning E-Module for Improving Students' Critical Thinking Skills. Hydrogen: Jurnal Kependidikan Kimia, 13(4), 751–765. https://doi.org/10.33394/hjkk.v13i4.16830

https://doi.org/10.33394/hjkk.v13i4.16830

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INTRODUCTION

Education is a dynamic process, meaning it requires continuous renewal and improvement (Junanto & Sartika, 2023). In Indonesia, the COVID-19 pandemic worsened the existing learning crisis, marked by increased learning loss and learning gaps (Kemdikbudristek, 2022). To address this, Kemdikbudristek implemented the Merdeka Curriculum in early 2022. The Merdeka Curriculum offers more relevant and interactive learning through project-based and problem-solving approaches. This gives students the space to explore current issues, strengthening their character and competencies in line with the Pancasila Student Profile (Kemdikbudristek, 2022).

Based on Permendikbudristek No. 262 of 2022, Chemistry is an optional subject at the high school/MA level. It's often seen as abstract, complex, and hierarchical (Pahriah & Hendrawani, 2019). A strong understanding of basic chemical concepts makes it easier for students to grasp more complex material, such as thermochemistry. This particular topic involves theories, formulas, calculations, and the study of energy in chemical reactions (Musbhirah et al., 2018; Kurnia et al., 2022). Pre-research surveys at SMAN 1 Kedamean, Gresik, revealed significant challenges. Fifty percent of students believed thermochemistry requires a deep conceptual understanding, and 58.82% emphasized the importance of memorizing formulas and

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calculation skills. The chemistry teacher further reinforced this, stating that student learning outcomes in this material tend to be low. This is likely due to a lack of active engagement in the learning process, which in turn impacts the development of students' critical thinking skills.

Critical thinking skills are essential for 21st-century learners, an era characterized by rapid technological advancement. Facione (2015) states that critical thinking can be developed through activities like interpretation, analysis, evaluation, inference, explanation, and self-regulation. However, the implementation of questions designed to measure these skills isn't yet widespread across all educational institutions, which means they're not optimally fostering students' higher-order thinking skills. One effective strategy for developing these skills is by implementing learning models that align with the characteristics of the material, such as Problem-Based Learning (PBL). PBL is a learning approach based on contextual problems that require investigative efforts to find solutions (Hendriana, 2018).

An individual's critical thinking ability can develop over time, especially when confronted with new problems or unresolved old issues. This happens because newly acquired information is stored in memory, then connected and reorganized with prior knowledge to achieve a goal or find an appropriate solution (Munawwarah, 2020). Through PBL, students gain experience in solving real-world problems and are trained to use communication, collaboration, and resource utilization skills in formulating ideas and developing reasoning abilities (Mustamin et al., 2024). The effectiveness of this model is also supported by Sari et al. (2019), who demonstrated that the PBL model positively impacts the improvement of critical thinking by fostering student independence and active engagement. However, interviews with a chemistry teacher at SMAN 1 Kedamean Gresik indicate that there are still obstacles in its implementation, particularly regarding the limitation of instructional materials that support the principles of the PBL model. Therefore, the innovative development of technology-based instructional materials is considered a potential solution to more effectively cultivate students' critical thinking skills in chemistry learning, by providing engaging and interactive learning media that leverage technological advancements.

Advancements in computer technology allow for the development of learning media that are more relevant to student needs (Ramadhani et al., 2022). Despite this, education in Indonesia still heavily relies on printed textbooks. This is evidenced by pre-research findings at SMAN 1 Kedamean Gresik, where 85.29% of students reported never having used electronic media, and 61.76% of students agreed that electronic media could make it easier for them to understand thermochemistry material. According to research conducted by Computer Technology Research (CTR), individuals only remember 20% of what they see and 30% of what they hear. However, memory retention increases to 50% when information is received visually and auditorily simultaneously, and reaches 80% if the information is also accompanied by direct action. Therefore, the utilization of interactive multimedia in the learning process is deemed necessary as it can enhance students' memory retention by allowing them to see, hear, and operate interactive multimedia concurrently. One form of interactive multimedia that can be developed for the learning process is a module.

In the rapidly evolving digital era, learning modules are increasingly presented in an electronic format, known as e-modules. E-modules represent an innovation in Information and Communication Technology (ICT)-based modules, offering numerous advantages over traditional printed modules. These include the integration of audio, video, animations, images, and interactive quizzes (Zainul, 2019). Typically, e-modules are packaged in a flipbook format, which is a digital animation that visually simulates turning pages of a book. One software tool for creating this type of e-module is Flip PDF Corporate Edition. This application provides an appealing and professional visual display, enhancing the material's attractiveness from the very first impression. Flip PDF Corporate Edition offers several advantages: it's compatible with

both Windows and Mac operating systems, has a simple registration process via email, and comes equipped with a variety of ready-to-use, customizable templates. Furthermore, users can import PDF files and add multimedia elements such as videos, audio, and active links. The available output formats include HTML, ZIP, EXE, APP, and FBR, allowing users to choose according to their needs (Anggraini & Puspasari, 2022). These advantages make Flip PDF Corporate Edition a powerful tool for developing engaging and interactive learning e-modules.

Despite numerous studies demonstrating the effectiveness of the Problem-Based Learning (PBL) model in enhancing students' critical thinking skills, and the widespread use of digital technology in developing interactive instructional materials, the combined application of both in the form of chemistry e-modules, particularly for complex topics like thermochemistry, remains limited. To date, there's a noticeable lack of research specifically developing and validating PBL-based chemistry e-modules equipped with interactive multimedia features. This indicates a significant gap in both scientific study and pedagogical practice, particularly concerning the provision of digital instructional materials that are not only visually engaging but also systematically effective in developing students' critical thinking skills. Therefore, this research aims to validate the content and construct of an e-module developed with Flip PDF Corporate Edition. This e-module is designed to address the aforementioned problems by enhancing students' critical thinking skills in the subject of thermochemistry.

METHOD

Research and development (R&D) methods aim to produce and test the effectiveness of a product (Sugiyono, 2018). Various models can be used in development research, with the choice depending on the level of application and the number of stages each model possesses. Therefore, when preparing instructional materials, it's crucial to consider the needs in the field and follow stages that align with appropriate development principles (Suhartati & Gipayana, 2017). This research uses an R&D (Research and Development) approach with the 4D development model. According to Thiagarajan, as cited in Sa'adah & Wahyu (2020), 4D research and development steps, namely define, design, develop, and disseminate. However, this particular research is limited to the define, design, and develop stages. The research design can be seen in Figure 1.

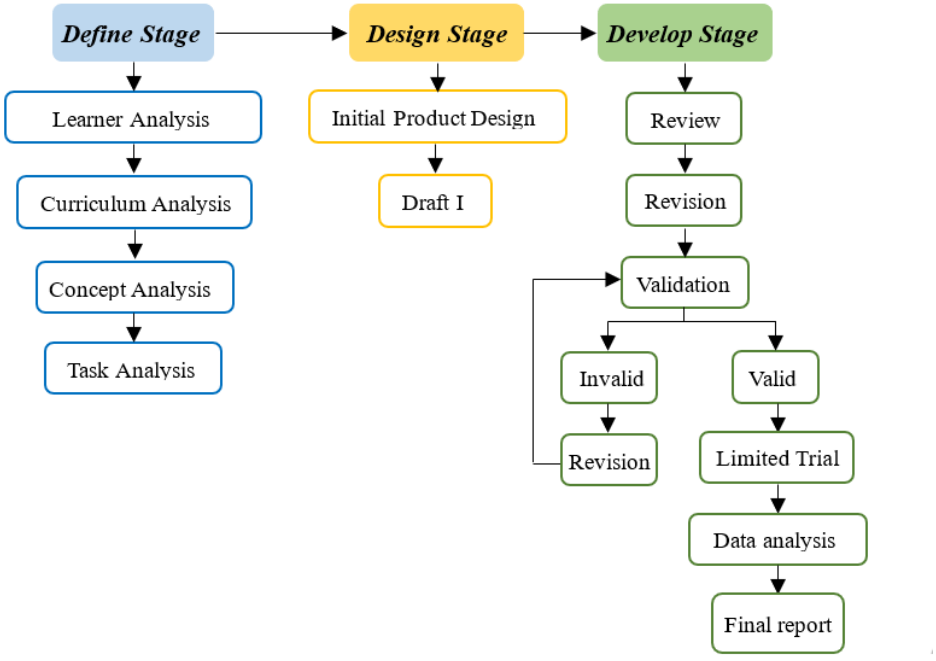

Figure 1. 4D Development Model Scheme

The developed learning e-module was first reviewed by the supervising lecturer, then moved to the validation stage. This stage aims to obtain data regarding the validity level of the e-module as an interactive teaching material. Validity itself refers to the extent to which an instrument can accurately measure what it is supposed to measure (Sugiyono, 2019). In this research, the validity assessment was conducted by three validators chosen based on their competency and scientific relevance in the field of instructional material development. The validators consisted of two chemistry education lecturers from Universitas Negeri Surabaya (Unesa) who are competent in developing chemistry learning media, and one chemistry teacher from SMAN 1 Kedamean Gresik, who has experience in implementing contextual learning in the classroom. The validation process focused on two main aspects: content validity and construct validity. Content validity covered the alignment of the material with Learning Outcomes (CP), Learning Objectives (TP), and the Merdeka Curriculum, conceptual accuracy, and the suitability of the e-module's content with the Problem-Based Learning (PBL) model and Critical Thinking Skills. The indicators on the validation instrument referred to the research findings of Pertiwi et al. (2024), which emphasize the quality of digital teaching materials. They suggest that interactive modules should be assessed based on content alignment with basic competencies and learning syntax, language readability, logical presentation flow, and visual appeal. The validation data were then analyzed using the modal score based on a Likert scale, as shown in Table 1 below.

Table 1. Likert Scale

Score	Cathegory
1	Very Bad
2	Bad
3	Fair
4	Good
5	Very Good

(Source: Riduwan 2015)

Based on the table above, the developed e-learning module can be interpreted as valid if it obtains a mode score ≥4 (Lutfi, 2021)

RESULTS AND DISCUSSION (12pt)

Before being implemented in chemistry learning, this e-module needs to undergo validation, focusing on content validity and construct validity. For product development, the researcher used S. Thiagarajan's 4D development model, which consists of four main stages: define, design, develop, and disseminate. However, this research was limited to only the define, design, and develop stages. The research findings based on the 4D model can be outlined as follows.

Define Stage

Learner analysis was conducted to identify the characteristics and critical thinking skills of students at SMAN 1 Kedamean, Gresik. This was done through interviews with the chemistry teacher, distributing response questionnaires, and administering critical thinking skills tests to students. This step revealed that students' thinking abilities were still low due to a lack of practice questions designed to promote critical thinking, and classroom learning was still largely dominated by the teacher's role.

Next, curriculum analysis was carried out to ensure that the developed curriculum aligned with student needs, educational goals, and the learning context. The curriculum used in this research was the Merdeka Curriculum. In the Merdeka Curriculum, learning plans are systematically developed through Learning Outcomes (CP), Learning Objectives (TP), and a Learning

Objective Flow (ATP). These are designed to ensure the achievement of student competencies in every subject, including thermochemistry (Kemdikbudristek, 2022). The Learning Outcomes (CP) used in this research are in Phase F. Phase F represents the learning phase for high school/MA/SMK/MAK grades XI and XII, reflecting the strengthening of academic competencies and students' readiness to proceed to higher education or the workforce (Kemdikbudristek, 2022).

Concept analysis aims to identify the main topics to be covered and arrange them systematically to form a concept map. A concept map is a hierarchical diagram-shaped visual strategy used to organize and connect concepts systematically, making it easier for students to understand and organize knowledge (Setiawan et al., 2016). This concept map is intended to help students grasp the thermochemistry material in broad strokes.

Finally, task analysis aims to identify and delineate the skills, knowledge, and steps that students must master to achieve learning objectives systematically. The developed learning e-module utilizes the Problem-Based Learning (PBL) model. PBL syntax consists of 5 phases, namely phase 1 (orienting students to the problem), phase 2 (organizing students for learning), phase 3 (guiding individual and group investigation), phase 4 (developing and presenting results), and phase 5 (Analyzing and evaluating the problem-solving process) (Hamid et al., 2022).

Design Stage

This stage aims to design learning tools, including the development of evaluation instruments and the planning of learning activities. This involves test construction, format selection, media selection, and initial drafting. Test construction is divided into two parts: a pretest given at the beginning and a posttest given at the end. Both are based on six indicators of critical thinking skills according to Facione (2015): interpretation, analysis, evaluation, inference, explanation, and self-regulation. The tests are in the form of 10 essay questions. This format was chosen because of its superiority in eliciting higher-order thinking skills. Unlike multiple-choice questions, which tend to test factual recognition, essay questions have the potential to reveal students' abilities to reason, create, analyze, and evaluate. For fostering deep understanding and higher-order thinking, essay questions are a more appropriate evaluation instrument than multiple-choice questions.

Research by Gupta et al. (2016) compared student preferences for essay and Multiple Choice Questions (MCQ); although MCQs were generally preferred, essays were considered more effective in testing critical thinking skills, argument organization, and conceptual understanding. In line with this, the chosen format for this research is a module. A module allows for systematic, interactive material presentation and can be combined with evaluative questions that encourage higher-order thinking, especially for abstract topics like thermochemistry. This learning module is packaged in an electronic format (e-module), utilizing the Flip PDF Corporate Edition application. The initial draft involves creating the preliminary design of the e-module as Draft I. This draft contains the e-module cover, preface, table of contents, a brief description of the e-module, instructions for using the e-module, a concept map, Learning Outcomes (CP), Learning Objectives (TP), Learning Objective Flow (ATP), learning activities, Learning Activity Performance Document (LAPD) incorporating Problem-Based Learning (PBL) and critical thinking skills, a glossary, and a bibliography.

Develop Stage

The development stage is a continuation of the design stage, encompassing review, validation, and limited trials. However, the researchers limited this study to the expert validation stage only. The following figures show the product of the development, an e-learning module assisted by Flip PDF Corporate Edition.

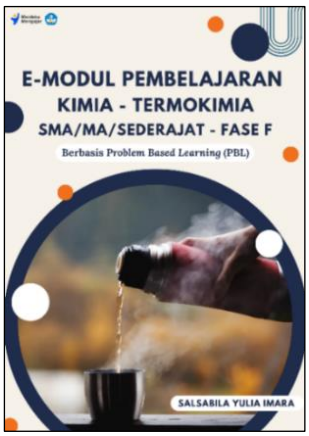

Figure 2. Cover of the e-module

Figure 3. Cover LAPD 1

Figure 4. Cover LAPD 2

Figure 5. Cover LAPD 3

Figure 6. Learning Activity 1

Figure 7. Learning Activity 2

Figure 8. Learning Activity 3

The e-learning module was first reviewed by the reviewer, the supervising lecturer, to receive comments and suggestions. The revised review results can be seen in Table 2.

Tabel 2. Revised Review Results

No.	Initial Draft	Revised Draft
1.	E-module usage instructions are unclear	Added features used in the e-learning module and their functions
2.	No explanation of PBL syntax	Added description of PBL syntax
3.	Inappropriate use of example images	Replaced cartoon images with more realistic images
4.	No explanation for displayed images	Provided explanations for displayed images

Next, the assessment by experts was conducted. This expert assessment, or validation, aims to determine the quality of a learning medium. The e-learning module was validated by three validators: two Unesa chemistry lecturers and one chemistry teacher from SMAN 1 Kedamean, Gresik.

The aspects assessed by the validators were content validity and construct validity. The assessment was carried out using a scoring scale of one to five for each question. The results of the content validity and construct validity can be seen in Table 3.

Table 3. Content and Construct Validity Results

Aspect	Mode	Category	Description
Content Validity	4	Good	Valid
Construct Validity	4	Good	Valid

Content validity is an aspect used to determine the extent to which the questions on a developed instrument and their scores accurately measure the skills intended to be assessed (Mohamad et al., 2015). The content validity of the developed e-learning module consists of four aspects: alignment of material with CP, TP, and ATP in the Merdeka Curriculum, alignment of content with the PBL model, accuracy of the material, and alignment of content with students' critical thinking skills. The validity results for each aspect can be seen in Table 4.

Table 4. The validity results for each aspect

No.	Assessed Aspect	Mode	Category	Description
1	Alignment of material in the e-learning module with Learning Outcomes, Learning Objectives, and Learning Objective Flow in the Merdeka Curriculum	4	Good	Valid
2.	Alignment of e-learning module content with the Problem-Based Learning (PBL) model	4	Good	Valid
3.	Accuracy of thermochemistry material in the e-module	4	Good	Valid
4.	Alignment of e-learning module content with students' critical thinking skills	4	Good	Valid

Alignment of E-Module Content with Merdeka Curriculum Standards

The core concept of the Merdeka Curriculum is to grant teachers the autonomy to design learning that aligns with students' characteristics and needs, while also providing space for students to be creative and develop their potential more independently (Sari & Sutrisno, 2022). The alignment of the e-module's content with the Learning Outcomes, Learning Objectives, and Learning Objective Flow is crucial. This is because each phase is structured to meet student needs and ensure targeted learning. This is supported by the statement from Kemdikbudristek (2022) that teachers need to adjust material and instruction based on the appropriate phase for the students' class level. Therefore, this learning e-module is designed using the PBL model as an effort to support the achievement of learning objectives more effectively.

This aspect received a validity score of 4 (good category) because the material in the e-module was deemed sufficiently aligned with the CP, TP, and ATP set in the Merdeka Curriculum. The presentation of the material followed a logical flow and was relevant to the competencies aimed for. The validators assessed that the e-module's content generally supports the achievement of learning objectives. However, some sections still require clarification, particularly in explicitly demonstrating the connection between learning activities and the CP, TP, and ATP. With improvements in these areas, the module has the potential to achieve a "very good" or "very valid" category.

Alignment of E-Module Content with Problem-Based Learning (PBL) Model

According to Setiawan et al. (2022), the PBL syntax consists of five phases: Phase 1 (orientation to the problem), Phase 2 (organizing students for learning), Phase 3 (guiding individual and group investigation), Phase 4 (developing and presenting artifacts), and Phase 5 (analyzing and evaluating the problem-solving process). According to Nuryanto et al. (2015), the PBL model is appropriate for thermochemistry material. Thermochemistry's characteristics involve calculations, concepts, and interconnections between concepts. Learning through problem-solving linked to daily life, packaged within the PBL model, is expected to help students understand and apply thermochemistry in calculations.

This aspect received a validity score of 4 (good category) because the e-module content adequately represents the Problem-Based Learning (PBL) syntax, from problem orientation to evaluation. It also includes student activities consistent with PBL characteristics, such as investigation, problem-solving, and presentation. Nevertheless, some parts still need strengthening, especially concerning more contextual problem stimuli and guidance for independent investigation. Therefore, while the e-module is rated as good, further improvements can be made to achieve a "very good" category.

Accuracy of Thermochemistry Material in the E-module

Beyond the learning model, the accuracy of the material content in the e-module, especially for thermochemistry, is a crucial aspect to consider. Vlachopoulos and Makri (2019) state that digital media must be able to bridge conceptual understanding with contextual learning experiences. Therefore, the selection of material in the e-module must be done carefully to prevent misconceptions among students. This aspect received a validity score of 4 (good category) because the thermochemistry material in the e-module is structured based on correct scientific concepts and reliable sources. The presentation of concepts and calculation examples is quite systematic, accurate, and relevant. However, some sections, such as the explanation of enthalpy and its application in real contexts, could still be clarified. Thus, while meeting content accuracy standards, the material's quality is still in the "good" category, not yet reaching "very good."

Alignment of E-module Content with Students' Critical Thinking Skills

The next aspect considered in the development of this e-module is the content's relevance to fostering students' critical thinking skills. The developed learning e-module utilizes six critical thinking skill indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2015; Fahrurrozi et al., 2018; Munawwarah et al., 2020). According to Kurniasih and Sani (2021), questions with critical thinking indicators illustrate students' capacity to logically and reflectively manage and assess information. Therefore, an e-module containing critical thinking-oriented questions significantly contributes to enhancing students' critical thinking abilities.

This aspect received a validity score of 4 (good category) because the e-module content facilitated most aspects of critical thinking skills, such as interpreting information, analyzing problems, explaining simple statements, and self-regulation at the end of learning. However, the stimuli for evaluation and inference are still not optimal because the activities in the e-module do not sufficiently encourage students to assess arguments or draw detailed conclusions. Therefore, the score given falls into the "good" category, as it has not yet fully promoted evaluation and inference skills to their maximum potential. Meanwhile, construct validity is a type of validity that indicates the extent to which an instrument truly measures the theoretical construct or concept it intends to measure. The construct validity of the developed learning e-module consists of three aspects: language, presentation, and graphics. The validation results for each aspect can be seen in Table 5.

Table 5. Construct Validity Results

No.	Assessed Aspect	Mode	Category	Description
1	Linguistics	4	Good	Valid
2.	Presentation	4	Good	Valid
3.	Graphics	4	Good	Valid

Language Aspect

The language aspect encompasses three indicators: using simple and easily understandable sentences, employing good and correct Indonesian, and ensuring sentences do not contain ambiguous meanings. This evaluation criterion aims to assess the clarity of information written in the learning e-module. The language used in learning media must be designed with an easy-to-understand, clear structure, and accurately reflect the content to effectively convey the learning message. In line with this, Astriani (2018) states that one criterion for good learning media is ease of use, meaning the learning media must be easy for students to understand, learn, and operate. The e-module received a good rating because the language used was considered quite effective, communicative, and easy to understand. However, some minor writing errors were still found, such as ineffective word placement, incorrect chemical element notation, and improper punctuation. This indicates that the language aspect has not fully met the criteria for accuracy and consistency in scientific writing, resulting in a score of 4 out of a maximum of 5.

Presentation Aspect

The presentation aspect covers six indicators: 1) clarity of objectives, 2) student motivation and curiosity, 3) attractiveness and enjoyment, 4) systematic order of material in the e-module, 5) material presentation encouraging active student engagement, and 6) appropriate and clear image presentation. A module is a complete unit of learning material designed holistically, containing a systematically arranged series of learning activities to facilitate independent student learning to achieve specific and clearly formulated learning objectives. Clarity of objectives helps students understand what needs to be achieved, making learning more focused and independent. In line with this, Orr et al. (2022) state that clearly structured learning objectives help students understand learning expectations and improve performance in formative and summative assessments.

Besides clear objectives, the order of the presented material must be systematic. According to Nufus et al. (2020), the presentation of a learning e-module must be concise, structured, to the point, and tailored to students' ways of thinking to prevent boredom while reading. Boredom can certainly be overcome with an e-module designed to be engaging and enjoyable, thereby increasing student motivation and curiosity, leading to active participation in learning activities.

According to Astriani (2018), in addition to being easy and relevant, learning media must be attractive or stimulate student attention, both in terms of appearance, color choices, and content. The last indicator relates to the presentation of appropriate and clear images. When images are presented appropriately and are communicative, they can further support student understanding. This aligns with Harsyanda et al. (2024), who emphasize that the clarity and relevance of images and student engagement are key to visual effectiveness in accelerating understanding and increasing learning interest.

In the presentation aspect, the e-module received a score of 4 (good category) because most indicators were met, such as clear objectives, coherent material, and supporting images. Although it was quite engaging and encouraged participation, visual and interactive elements still need to be improved to strengthen curiosity and the learning experience.

Graphical Aspect

The validation assessment for the graphical criteria in the e-module covers four main indicators: (1) an attractive cover that represents the e-module's content, (2) appropriate use of font type and size, (3) suitable color composition that does not interfere with readability, and (4) the presence of relevant supporting illustrations, graphics, images, or photos. The e-module cover uses an illustration of boiling water emitting steam, taken from the researcher's personal documentation. This visual was chosen to represent the core of the e-module's content, namely thermochemistry, which discusses heat transfer in systems and the environment. The alignment of graphical elements in the e-module with the learning content is crucial as it can help students focus more, be interested, and understand the material better.

According to Mayer and Fiorella (2022), in The Cambridge Handbook of Multimedia Learning, the application of the Cognitive Theory of Multimedia Learning principles in graphic design, which includes the integration of visuals with text and the proportional use of color, plays a vital role in enhancing learning quality. Properly designed graphics not only strengthen students' cognitive engagement but also improve conceptual understanding and memory retention more optimally. This is also supported by guidelines from Kemdikbudristek (2022), which state that cover designs must clearly and relevantly reflect the content to be conveyed and possess visual appeal.

The visual appeal in learning media is greatly influenced by the selection and composition of colors used. Appropriate colors not only enhance aesthetics but also contribute to increasing student focus, attention, and cognitive engagement. Research by Gong et al. (2024) reveals that although background color does not always directly impact content comprehension, its presence is significant in increasing user satisfaction and engagement with digital materials. Meanwhile, Apriadi et al. (2024) proved that Problem-Based Learning (PBL)-based e-modules with representative visual elements can enhance students' critical thinking skills. This finding confirms that the visual design of a module does not merely beautify the appearance but also plays an important role in supporting learning outcomes. This finding emphasizes that visual elements not only enhance the appearance but also strengthen comfort, motivation, and the effectiveness of student learning outcomes.

In addition to color selection, the appropriate use of font type and size, as well as illustrations, are also important aspects that affect readability and learning effectiveness in e-modules. Using appropriate fonts and proportional font sizes not only beautifies the appearance but also helps students read, understand, and absorb information optimally. The use of images can help students understand and connect the concepts being learned with the real world.. This aligns with the urgency of developing e-modules for thermochemistry material, which is one of the chemistry topics with a high level of abstraction and often causes misconceptions among students. Thus, the appropriate presentation of images in the e-module not only clarifies the material but also bridges the gap between abstract concepts and students' concrete experiences in daily life.

In the graphical aspect, the e-module received a good rating because it included a representative cover design, harmonious color selection, and supporting illustrations for the material. Nevertheless, inconsistencies were still found in the use of font types and sizes, as well as disproportional image layouts. These shortcomings affect visual harmony and reading comfort, thus this aspect was deemed not optimal enough to achieve a "very good" category.

Based on the validation results, the developed e-module demonstrates several strengths in supporting both independent and collaborative learning. This module is designed with high flexibility, allowing students to learn individually or in groups with teachers or peers, in line with the Problem-Based Learning (PBL) model used. This e-module is also specifically

designed to foster critical thinking skills through systematically arranged indicators. One of the key features of this e-module is the feedback mechanism, which allows students to perform independent self-evaluation.

Additionally, the module is user-friendly, meaning it's easily accessible and portable because it's presented in a digital format. The attractive visual design, integration of interactive multimedia elements, and presentation of material within real-world problem contexts also contribute to increasing learning motivation and cognitive engagement of students. However, the use of this e-module also has some limitations that need consideration. Dependence on digital devices and stable internet access is a primary obstacle, especially for students in areas with limited infrastructure. Furthermore, adapting to the digital format might be a challenge for students who are more accustomed to using printed learning media. From a technical perspective, the visual and interactive elements can still be enhanced to further strengthen student engagement.

CONCLUSION

Based on the validation results from three experts, the developed learning e-module was declared valid in both its content and construct aspects, achieving a modal score of 4, which falls into the "good" category. This shows that the research objective, namely developing and testing the validity of the content and construct of e-modules to support students' critical thinking skills, has been achieved. The novelty of this research lies in the combination of the Problem-Based Learning (PBL) model with the interactive multimedia features of Flip PDF Corporate Edition in chemistry learning, particularly for complex material like thermochemistry. This study makes a tangible contribution to the development of digital instructional materials, where the developed e-module has the potential to be used as an interactive learning medium at the high school level, both for independent study and collaborative classroom learning, and can be applied to other subjects. Thus, these findings provide an innovative alternative for improving the quality of chemistry education, making it relevant to the demands of 21st-century skills, especially critical thinking.

RECOMMENDATIONS

Based on these conclusions, it is recommended that future research be conducted to assess the feasibility of the e-learning module in terms of practicality and effectiveness to gain a more comprehensive understanding of the developed e-learning module's quality.

ACKNOWLEDGEMENTS

This research was successfully carried out thanks to the support of various parties. Therefore, the researchers extend their gratitude to the supervising lecturers for their guidance and direction throughout the research, to the validators for validating every instrument used in the study, to the school, teachers, and students who participated and supported the execution of this research, and to all parties involved in the study.

BIBLIOGRAPHY

Anggraini, V. A., & Puspasari, D. (2022). Pengembangan Bahan Ajar Interaktif Berbasis Flip PDF Coorporate pada Materi Media Komunikasi Kehumasan Kelas XI OTKP 2 di SMKN 10 Surabaya. *Jurnal Pendidikan dan Konseling (JPDK)*, *4*(5), 2219–2232.

Apriadi, R., Agustini, K., & Parwati, N, N. (2024). E-Modul Fikih Berbasis Problem Based Learning untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Madrasah Ibtidaiyah. *Jurnal Media dan Teknologi Pendidikan, 4*(4), 589-596.

Astriani, S. A. (2018). *Prinsip dan Kriteria Pemilihan Media Pembelajaran*. Probolinggo: Universitas Nurul Jadid.

Facione. (2015). *Critical thinking: What It Is and Why It Counts.* California: Measured Reasons and The California Academic Press.

Fahrurrozi, Hulyadi, & Pahriah. (2018). Pengembangan Bahan Ajar Ikatan Kimia Model Inkuiri dengan Strategi Konflik Kognitif Terhadap Kemampuan Berpikir Kritis. *Hydrogen: Jurnal Kependidikan Kimia. 7*(1), 12-24

Gong, Z., Lee, S., Westland, S, Henry, P., & Queiroz, F. (2024). Effect of background colours in digital material on comprehension. *Journal of the International Colour Association,37*(1), 36-47

Gupta, C., Jain, A., & Souza, A, S, D. (2016). Essay Versus Multiple-Choice: A Perspective from the Undergraduate Student Point of View with its Implications for Examination. *Gazi Medical Journal, 27*(1), 8-10

Hamid, N., Dasna, Wayan I., & Habiddin, H. (2022). Kajian Literatur: Implementasi Problem Based Learning (PBL) Dalam Pembelajaran Kimia. *Hydrogen: Jurnal Kependidikan Kimia. 10*(2), 209-223

Harsyanda, E, F., Luthviyah, S., Manda, A., & Kurnia, B. (2024). Penggunaan Media Gambar Dalam Pembelajaran Bahasa Indonesia Kelas V. *JAMPARING: Jurnal Akuntansi Manajemen Pariwisata dan Pembelajaran Konseling, 2*(2), 737-743

Hendriana, E. C. (2018). Pengaruh Model Pembelajaran *Problem Based Learning* dan Gaya Belajar Auditorial terhadap Hasil Belajar IPS di Sekolah Dasar. *JPDI (Jurnal Pendidikan Dasar Indonesia), 3*(1), 1-8.

Junanto, T., & Sartika, R, P. (2023). Penerapan Model Pembelajaran Team Based Learning untuk Meningkatkan Keterampilan Abad 21 bagi Mahasiswa Calon Guru Kimia. *Hydrogen: Jurnal Kependidikan Kimia, 11(*6), 969 – 982

Kemdikbudristek. (2022). *Capaian Pembelajaran Mata Pelajaran Kimia Fase E - Fase F Untuk SMA/MA/Program Paket C*. Jakarta: Kemdikbudristek

Kemdikbudristek. (2022). *Panduan Pembelajaran dan Asesmen*. Jakarta: Kemdikbudristek

Kemdikbudristek. (2022). *Perubahan Atas Keputusan Menteri Pendidikan, Kebudayaan, Riset, dan Teknologi Nomor 56/M/2022 Tentang Pedoman Penerapan Kurikulum dalam Rangka Pemulihan Pembelajaran.* Jakarta: Kemdikbudristek

Kurnia, L. D., Haryati, S., & Linda, R. (2022). Pengembangan instrumen evaluasi higher order thinking skills menggunakan quizizz pada materi termokimia untuk meningkatkan kemampuan berpikir tingkat tinggi peserta didik. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education), 10*(1), 176-190.

Kurniasih, R., & Sani, B. (2021). Pengembangan soal HOTS berbasis indikator berpikir kritis. *Jurnal Pendidikan dan Pembelajaran, 28*(1), 55–62

Lutfi, A. (2021). Research and Development (R&D): Implikasi dalam Pendidikan Kimia. Universitas Negeri Surabaya.

Mayer, R., & Fiorella, L. (2022). *The Cambrige Handbook of Multimedia Learning* (3rd ed) (pp. 3-16). Cambrige: Cambrige University.

Mohamad, M, M., Sulaiman, N, S., Sern, L, C., & Salleh, K,M. (2015). Measuring the Validity and Reliability of Reseach Instruments. *Procedia–Social and Behavioral Sciences, 204*(1), 164-171

Munawwarah, M., Laili, N., & Tohir, M. (2020). Keterampilan Berpikir Kritis Mahasiswa dalam Memecahkan Masalah Matematika Berdasarkan Keterampilan Abad 21. *Alifmatika: Jurnal Pendidikan dan Pembelajaran Matematika. 2*(1). 37-58

Musbhirah, Q. U., Muntari, M., & Idrus, S. W. (2018). Pengaruh Model Pembelajaran Joyful Learning Dengan Media Kartu Aksi Terhadap Hasil Belajar Kimia Materi Koloid Pada Siswa Kelas XI MIA MAN 2 Model Mataram. *Chemistry Education Practice, 1*(1), 28-33.

Mustamin, K., Wahdah., Intiardy, D., Jumrah, A, M., & Pattiasina, P, J. (2024). The Impact of Project-Based Learning on Students' Collaboration Skills in Secondary Schools. *International Journal of Educational Research Excellence (IJERE), 3*(2) 992-998

Nufus, H., Susilawati., & Linda, R. (2020). Implementation of E-Module Stoiciometry Based on Kvisoft Flipbook Maker for Increasing Understanding Study Learning Concepts of Class X Senior High School. *JOURNAL OF EDUCATIONAL SCIENCES*, *4*(2), 261-272

Nuryanto, Utami, B., & C.S, A. N. (2015). Penerapan Model Pembelajaran *Problem Based Learning* (PBL) dilengkapi *Macromedia Flash* untuk Meningkatkan Kemampuan Berpikir Kritis dan Prestasi Belajar Siswa pada Materi Pokok Termokimia Kelas XI Siswa SMA Negeri 2 Karanganyar Tahun Pelajaran 2014/2015. *Jurnal Pendidikan Kimia (JPK), 4*(4), 87-94.

Orr, R., Csikari, M., Freeman, S., & Rodriguez, M, C. (2022). Writing and Using Learning Objectives. *CBE-Life Science Education, 21*(3), 1-6

Pahriah & Hendrawani. (2019). Efektivitas Modul Inkuiri Dengan Strategi Konflik Kognitif Dalam Meningkatkan Keterampilan Berpikir Kritis Mahasiswa. *Hydrogen: Jurnal Kependidikan Kimia. 7*(2), 62-72

Ramdhani, W, R., Syamsurizal, & Afrida. (2022). Multimedia Interaktif Menggunakan Articulate Storyline Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Pada Materi Larutan Penyangga. *Hydrogen: Jurnal Kependidikan Kimia. 10*(2), 197-208

Sa'adah, R, N., & Wahyu. (2020). *Metode Penelitian R&D (research and development): Kajian Teoritis dan Aplikatif.* Malang: Literadi Nusantara.

Sari, S. P., Koeswanti, H. D., & Giarti, S. (2019). Penerapan Model Pembelajaran Problem Based Learning Untuk Meningkatkan Keterampilan Berpikir Kritis Pada Muatan Matematika Kelas 4. *Jurnal Basicedu*, *3*(2), 378-386.

Sari, N., & Sutrisno, A. (2022). Penerapan kurikulum merdeka dalam meningkatkan keaktifan siswa pada pembelajaran PAK. *Jurnal Ilmu Pendidikan, 29*(3), 143–156.

Setiawan, B., Astriani, D., & Budiyanto, M. (2016). Penerapan Strategi Belajar Peta Konsep Untuk Meningkatkan Hasil Belajar Mahasiswa Pada Mata Kuliah Sains Sekolah Prodi S-1 Pendidikan Ipa Unesa Surabaya. *JPPIPA (Jurnal Penelitian Pendidikan IPA), 1*(1), 37-42.

Setiawan, T., Sumilat, J, M., Paruntu, N, M., & Monigir, N, N. (2022). Analisis Penerapan Model Pembelajaran Project Based Learning dan Problem Based Learning pada Peserta Didik Sekolah Dasar. *Jurnal Basicedu, 6*(6), 9736-9744.

Sugiyono. (2018). *Quantitative, qualitative, and R&D research methods.* Bandung: Alfabeta.

Sugiyono. (2019). *Metodelogi Penelitian Kuantitatif, Kualitatif dan R&D*. Bandung: Alfabeta.

Suhartati, S., & Gipayana, M. (2017). Bahan pembelajaran berbasis budaya daerah istimewa Yogyakarta yang berkualitas. *Prosiding Seminar Nasional Mahasiswa Kerjasama Direktorat Jenderal Guru Dan Tenaga Kependidikan* Kemendikbud, 1–6

Suyanto, M. (2005). *Multimedia Alat Untuk Meningkatkan Keunggulan Bersaing*. Yogyakarta: Andi Offset.

Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: a systematic literature review. *International Journal of Educational Technology in Higher Education, 14*(22), 1-33.

Zainul, V. K. (2019). Pengembangan E-Modul Berbasis Inkuiri Terbimbing Pada Materi Sifat Keperiodikan Unsur Untuk SMA/MA Kelas X. *Jurnal EduKimia, 1,* 28-36