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Development of a PBL Integrated STEM E-Module on the Reaction Rate Topic

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Abstract: Development of a PBL Integrated STEM (Science, Technology, Engineering, and Mathematics) E-Module on the Reaction Rate Topic. This study aims to develop a Problem Based Learning (PBL) e-module integrated with Science, Technology, Engineering, and Mathematics (STEM) on the topic of Reaction Rate for Grade XI students at SMA Swasta Kartika I-2 Medan. The development model used in this research is the 4D model, which consists of four stages: Define, Design, Develop, and Disseminate; however, this research was limited to the Develop stage. The results showed that the PBL-based STEM-integrated e-module has a very high level of validity based on assessments from seven validators, consisting of three expert lecturers and four chemistry teachers. The material aspect obtained a feasibility percentage of 89.0%, and the media aspect obtained 87.4%, both categorized as *very valid*. Therefore, the reaction rate e-module based on the Problem-Based Learning (PBL) approach integrated with Science, Technology, Engineering, and Mathematics (STEM) can be further implemented in the trial phase of chemistry learning.

Keywords: E-Module Development, PBL, STEM, Reaction Rate, 4D Model

Abstrak: Pengembangan E-Modul Berbasis PBL Terintegrasi STEM (Science, Technology, Engineering, And Mathematics) Pada Materi Laju Reaksi. *Penelitian ini bertujuan untuk mengembangkan e-modul berbasis Problem Based Learning (PBL) terintegrasi Science, Technology, Engineering, and Mathematics (STEM) pada materi Laju Reaksi untuk peserta didik kelas XI di SMA Swasta Kartika I-2 Medan. Model pengembangan yang digunakan dalam penelitian ini adalah model 4D, yang terdiri atas empat tahapan, yaitu Define, Design, Develop, dan Disseminate, namun penelitian ini dibatasi sampai pada tahap Develop. Hasil penelitian menunjukkan bahwa e-modul berbasis PBL terintegrasi STEM memiliki tingkat validitas yang sangat baik berdasarkan hasil penilaian tujuh validator, terdiri dari tiga dosen ahli dan empat guru kimia. Aspek materi memperoleh persentase kelayakan sebesar 89,0% dan aspek media sebesar 87,4%, keduanya termasuk dalam kategori sangat valid. Maka e-modul laju reaksi berbasis Problem Based Learning (PBL) terintegrasi Science, Technology, Engineering, and Mathematics (STEM) dapat dilanjutkan pada tahap uji coba dalam pembelajaran kimia.*

Kata kunci: *Pengembangan E-Modul, PBL, STEM, Laju Reaksi, Model 4D*

INTRODUCTION

Entering the 21st century, education faces a number of significant challenges that require serious attention to develop a system that is relevant, inclusive, and competitive. These challenges have become increasingly apparent in the context of rapid technological

advancement, globalization, and continuous social dynamics, which demand the education sector to address various complex issues that are highly relevant to the needs of the modern era (Isma et al., 2023). With the emergence of the Industrial Revolution 4.0, the 21st century is characterized by globalization and openness. In this context, Indonesia is currently undergoing an industrial revolution phase; however, its education level remains relatively low compared to other countries. This indicates that improving Indonesia's education system is essential to produce an excellent generation capable of competing globally and keeping pace with the ongoing transformations of the times (Mardhiyah et al., 2021).

The 2019 report from the Policy Research Center of the Ministry of Education and Culture (Kemendikbud) revealed that Indonesia's National Reading Literacy Activity Index (Alibaca) was at 37.32%, which falls into the low category. In addition, Indonesia ranked 64th out of 72 participating countries in the 2015 Programme for International Student Assessment (PISA) survey. These results reflect ongoing issues within Indonesia's learning process and highlight the urgent need to improve the education system to address these challenges. Since 2016, the government, through the Ministry of Education and Culture, has launched the National Literacy Movement (Gerakan Literasi Nasional, GLN), which includes the School Literacy Movement (Gerakan Literasi Sekolah, GLS), the Family Literacy Movement, and the Community Literacy Movement (Solihin et al., 2019).

Considering the widespread use of gadgets among students, the government must enhance digital literacy, defined as the ability to effectively use information technology and communicate. With advances in information technology, individuals can access information from various digital platforms, allowing learning materials to be more flexible and adaptable to ongoing technological developments (Munawaroh et al., 2022). Only 13.9% of students use digital devices for less than one hour per day, while the majority spend more than two hours (Chalim & Anwas, 2018).

Textbook examples are often not contextualized to daily life, making it difficult for students to see practical applications, while the lack of supplementary resources limits engagement. Developing interactive and relevant learning materials is therefore essential at SMA Swasta Kartika I-2 Medan. The grade XI reaction rate topic relates closely to everyday life and can be explored through experiments. A Problem Based Learning (PBL) e-module integrated with STEM offers an effective approach, promoting active participation, hands-on learning, and deeper understanding of chemical concepts. Through this type of learning, students not only acquire broad knowledge but also learn how to apply that knowledge in situations related to the field of study being explored (Rachmawati et al., 2017).

STEM-based education (Science, Technology, Engineering, and Mathematics) plays a vital role in developing human resources who are able to think critically, logically, and systematically. This approach not only emphasizes conceptual mastery but also the application of skills in solving real-world problems (Fadila et al., 2025). With the integration of STEM, students are able to develop deeper insights, become more dynamic and creative in their thinking, and strengthen essential competencies needed to shape a superior and competitive future generation (Dalimunthe et al., 2025). In addition, the implementation of STEM in learning is believed to create more meaningful learning experiences, as students not only understand concepts theoretically but are also able to connect them with real-life contexts, thereby making the learning process more relevant and effective.

PBL strengthens students' competencies in addressing complex learning challenges and prepares them to succeed in real world situations that are dynamic and demanding (Lee & Blanchard, 2019). The STEM approach integrates science, technology, engineering, and mathematics within the educational process. It emphasizes the development of the 4C, creativity, critical thinking, collaboration, and communication which help students devise innovative solutions to problems and communicate them effectively (Lestari et al., 2018). Therefore, integrating the STEM approach with PBL can enhance the effectiveness of learning, as STEM encourages students to apply interdisciplinary knowledge in real-world contexts. This e-module combines PBL and STEM to strengthen students' understanding through the integration of theory and practice. Students not only learn reaction rate concepts theoretically but also observe the practical applications of technology and engineering, while developing mathematical skills to analyze experimental data.

The study conducted by Dibyantini & Sulastri (2023) on the development of a problem-based chemistry e-module for the topic of reaction rates concluded that the e-module met the BSNP (National Education Standards Agency) criteria. The data analysis results showed that the content feasibility scored 3.69, language feasibility 3.7, presentation feasibility 3.62, and graphical feasibility 3.78. Based on these findings, the e-module was declared suitable for use as a learning material in chemistry instruction. Furthermore, research by Putri, Anwar, and Hardin (2023) on a PBL-based chemistry practicum module for the reaction rate topic in grade XI students at SMA Negeri 3 Makassar found that the PBL-based practicum module developed for grade XI students was valid, practical, and effective, as reflected by an 88.8% class completion rate.

A study conducted by Aulya, Raisha Amayati Asyhar & Yusnaidar (2021) on the development of a PjBL-STEM based Chemistry E-Module on the *Buffer Solution* topic showed that validation by material experts, instructional design experts, and media experts fell into the very feasible category. Practically, teacher evaluations scored 95.71%, while student responses reached 87%, both classified as very good. Based on these results, the PjBL-STEM based e-module was considered suitable for use in chemistry learning. Dibyantini, Amdayani, Siregar, & Syafriani (2023) implemented a STEM-PjBL based chemistry e-module improved students' scientific literacy and learning motivation, with gains of N-Gain = 0.46 and motivation increasing from 76% to 87%. Collectively, these findings confirm that PBL-STEM–based e-modules are effective in enhancing understanding, critical thinking, and motivation, making them highly relevant for complex topics such as reaction rates.

Although previous studies have successfully developed e-modules based on PBL, STEM, or a combination of both, most of these developments have focused on topics other than reaction rates, such as buffer solutions or organic compounds. This study offers a more comprehensive e-module development that is not only valid in terms of content and media but also more contextual, applicable, and aligned with the learning demands of 21st-century chemistry education.

METHOD

This study employed a Research and Development (R&D) approach aimed at developing and validating a STEM-integrated PBL-based e-module on Reaction Rate material. The study adopted the R&D model using the 4D method (Thiagarajan, Semmel, & Semmel, 1974) . The Research and Development (R&D) method is a research approach designed to produce a product and test its effectiveness in use. This study is a research

method that validates the development of a product (Sugiyono, 2013). However, the research was limited to three stages Define, Design, and Develop because the focus of this study was to evaluate the feasibility of the PBL based e-module integrated with the STEM approach on the reaction rate topic. The *Disseminate* stage was not carried out because this research focused only on the development process and the initial validation of the product, without proceeding to the wider dissemination or implementation phase. This limitation was made to align with the available time, the scope of the study, and the main objective of the research, which emphasized assessing the feasibility of the product.

The subject of this study is a STEM integrated PBL based e-module, while the object of the study is the Reaction Rate material. The e-module developed in this research will be validated by three chemistry lecturers and four chemistry teachers who serve as expert validators in both material and media aspects. The data collection techniques used in this study include interviews, literature review, and questionnaires. Direct interviews will be conducted to identify problems that occur in schools and the challenges faced by teachers in teaching. The interviewees in this study are chemistry teachers of grade XI and students of grade XI Science 4. In addition, the literature review is carried out through an analysis of the reaction rate material, which includes learning outcomes (CP), learning objectives flow (ATP), concept analysis, and a review of theories related to e-modules and similar research products obtained from previous research and evaluation documents.

The validation sheets were used to assess the feasibility and quality of the PBL-based e-module integrated with the STEM approach on the reaction rate material. The instrument consisted of a Likert-scale questionnaire (1–4) adapted from BNSP standards and was administered to three chemistry lecturers as material and media experts, as well as four chemistry teachers. The material experts evaluated aspects of content feasibility, presentation feasibility, and contextual feasibility, while the media experts assessed graphical feasibility, language feasibility, and presentation/accessibility aspects.

This study produced two types of data: quantitative and qualitative. Quantitative data came from questionnaire scores by validators and teachers assessing the e-module, while qualitative data were obtained from their feedback and suggestions. After collecting the scores and responses from the material and media experts, the data were analyzed using a Likert scale. The data collected in the form of checklist items were summarized into a Likert scale format with assigned scores, as presented in the Table 1.

Table 1. Criteria for Validation Instrument Items Using the Likert Scale

No	Response Option	Score
1	Strongly Agree	4
2	Agree	3
3	Disagree	2
4	Strongly Disagree	1

Furthermore, validation sheets were used to assess the feasibility of the STEM-integrated PBL e-module on the Reaction Rate topic. The sheets, adapted from BSNP feasibility standards, were administered to three chemistry lecturers and four chemistry teachers as material and media expert validators. The obtained percentages for each category were then classified and analyzed qualitatively through descriptive interpretation, as presented in Table 2.

Table 2. Percentage of E-Module Validation Assessment

Percentage Interval (%)	Criteria	Description
85,01 - 100	Very Valid	The e-module can be used without revision.
70,01 - 85,00	Valid	The e-module can be used with minor revisions.
50,01 - 70,00	Less Valid	The e-module is not recommended for use because major revisions are needed.
01,00 – 50,00	Invalid	The e-module should not be used.

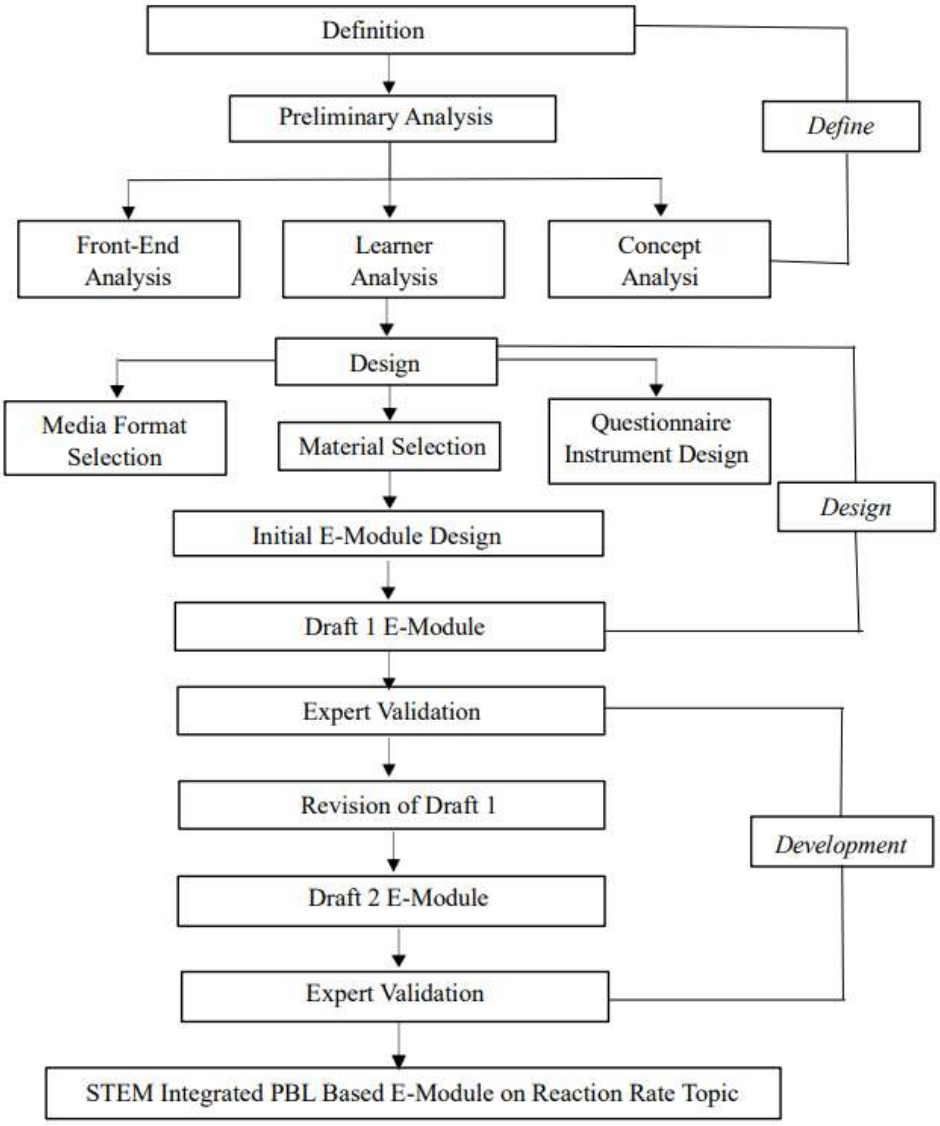

Figure 1. Research and Development Procedure of the STEM Integrated PBL Based E-Module on Reaction Rate Topic

RESULT AND DISCUSSION

Define Stage

The define stage is the initial phase in developing a STEM integrated Problem Based Learning (PBL) e-module, which aims to identify learning needs, learner characteristics, as well as the material and learning objectives to be developed. Based on interviews with teachers and students at SMA Swasta Kartika I-2 Medan, it was found that chemistry learning particularly on the reaction rate topic still relies on printed teaching materials that have not yet integrated the PBL-STEM model. Both teachers and students expressed the need for more interactive and engaging learning materials that align with the demands of digital-based learning. Students showed interest in using digital media and e-modules; however, they still experienced difficulties in understanding concepts and applying chemical formulas. Therefore, an innovative learning material is needed to facilitate independent and contextual learning.

Furthermore, the analysis of student characteristics revealed that most students feel bored when learning through textbooks and require learning media that are more visual, practical, and easy to understand. Concept analysis also indicated that existing chemistry textbooks have not fully adopted the PBL and STEM approaches. Hence, the developed e-module needs to be designed using simple language, engaging illustrations, and project based activities that connect theory with real life contexts. The formulated learning objectives emphasize students' ability to understand factors affecting reaction rates, analyze experimental results, and apply concepts in real-world situations. Thus, this define stage serves as an essential foundation for developing a PBL-STEM-based e-module that can enhance students' understanding, motivation, and critical thinking skills.

Design Stage

The design stage is the subsequent phase in developing a STEM-integrated Problem-Based Learning (PBL) e-module, focusing on planning and organizing the e-module components based on the needs analysis conducted during the define stage. The selected topic, *Reaction Rate*, was chosen because it is conceptually complex yet highly relevant to real-life phenomena and supports the development of critical thinking and problem-solving skills through the STEM approach. Based on an analysis of four high school chemistry textbooks commonly used by teachers for this topic, the detailed materials to be presented in the e-module are summarized in Table 3.

Table 3. Details of Reaction Rate Material

Subject Matter	Sub Subject Matter
Reaction Rate	1. Concept of Reaction Rate 2. Collision Theory
Factors Affecting the Reaction Rate	1. Concentration 2. Surface Area 3. Temperature 4. Catalyst
Reaction Order and Rate Constant	1. Rate Law 2. Reaction Order 3. Determination of Rate Law and Reaction Order 4. Reaction Mechanism

E-module was designed using Microsoft Word and Canva for layout processing and then uploaded to the AnyFlip platform for digital access. The structure of the e-module consists of three main sections introduction, content, and conclusion which are organized systematically and interactively. The e-module is also equipped with various supporting features such as barcodes, illustrations, instructional videos, and interactive quizzes to help students better understand concepts through contextual and engaging learning experiences. Warman (2025) states that effective learning materials should be able to capture students' attention, encourage active engagement in the learning process, and be organized systematically for easy understanding. In addition, the developed learning materials should utilize media and technology that align with students' characteristics to create a more meaningful and effective learning experience. During the design process, the researcher also determined a consistent formatting style to ensure that the e-module appears neat and easy to read. The format used includes A4 paper size (210 mm x 297 mm) with portrait orientation and 2.54 cm margins on all sides (right, left, top, and bottom). The fonts used are Arial, Segoe UI, and Segoe UI Black, with different sizes based on their functions. Chapter titles are set in size 14 bold, subchapter titles in size 12 bold, main text in size 12, captions for images or tables in size 9, and sources or links in size 8.

In addition to content development, the design stage also includes the creation of validation questionnaire instruments administered to material and media experts to assess the feasibility of the e-module in terms of content, language, presentation, and graphics. The instruments were developed using a four-point Likert scale with comment sections that allow validators to provide qualitative feedback for improving the product. The initial draft of the e-module consists of PBL-STEM based learning components, such as interactive quizzes, contextual problem examples, as well as student activities and worksheets (LKPD) that encourage concept application through experimentation and data analysis. Based on the results of the initial validation, the e-module was declared feasible with minor revisions to enhance the quality of content and design, making it an effective and engaging digital learning material for the *Reaction Rate* topic.

Develop Stage

The develop stage is the continuation of the design phase, aiming to produce a more refined and feasible version of the STEM integrated Problem Based Learning (PBL) e-module on the *Reaction Rate* topic. At this stage, the initial draft of the e-module that had been designed was validated by three chemistry lecturers from Universitas Negeri Medan and four chemistry teachers from SMA Swasta Kartika I-2 Medan. The validation process was conducted in July 2025 using a Likert scale questionnaire (1–4), which covered several aspects, including content feasibility, language, presentation, contextual relevance, and integration with the PBL-STEM approach. The results of the validation indicated that the developed e-module was feasible for use, with minor revisions suggested to improve both the content and visual presentation. Based on the results of validation and feedback from experts, several revisions were made to make the e-module more engaging, consistent, and aligned with effective learning principles. The evaluation results from the material expert validators included several suggestions for improving the developed e-module to enhance its quality and usability in the learning process. The detailed suggestions for improvement from the material expert validators are presented in Table 4.

Table 4. Revision Results of the PBL-STEM Integrated E-Module on Reaction Rate Material

No	Suggestion	Improvement
1	The e-module cover should include illustrations relevant to the topic of reaction rate.	Added supporting illustrations related to the reaction rate topic to make the cover more attractive and contextual.
2	The wording in the foreword, preface, and practice sections was inconsistent and ineffective.	Revised the wording to be clearer, more concise, and in accordance with academic language standards.
3	The font size in several parts of the module was inconsistent.	Adjusted font sizes: figure captions (10), sources (8), and main text (12) for better readability.
4	The barcode did not contain active links to additional learning resources.	Added active hyperlinks to each barcode for easier access to supplementary materials.
5	The Engineering example (tape) was inconsistent with the Science and Technology examples (yogurt).	Replaced the tape example with yogurt and added an explanation of the health benefits of yogurt in the Science aspect.
6	There were errors in the writing of indices and phases in the comprehension test section.	Corrected the writing of chemical indices and phases according to proper chemical notation.
7	Learning outcomes were not yet included in the e-module.	Added learning outcomes aligned with the *Merdeka Curriculum* in the introductory section.
8	Learning objectives and flow were not organized systematically.	Rearranged the learning objectives and their flow to ensure logical and systematic presentation.
9	The number of example questions was still limited.	Added more varied example questions to strengthen students' conceptual understanding.
10	The e-module did not include the author's biography.	Added a brief author biography at the end of the e-module.
11	The practice questions did not include answer keys.	Added an answer key section at the end of the module to facilitate student self-evaluation.

The implementation of PBL integrated with STEM in this e-module is designed to facilitate contextual learning that fosters students' critical, creative, and collaborative thinking skills. The Reaction Rate material was developed by integrating the four main aspects of STEM: Science, in understanding the concepts of factors affecting reaction rates; Technology, through the use of experimental tools such as fermenters; Engineering, in designing and analyzing the fermentation process; and Mathematics, through calculating reaction rates based on experimental data. For example, in the topic of catalysts, students analyze the effect of catalysts on the yogurt fermentation process, while in the reaction order topic, they calculate the rate constant based on data from vitamin C degradation. Thus, the developed e-module functions not only as a digital learning resource but also as an innovative learning medium that integrates scientific concepts with real life applications.

The design of the STEM-integrated PBL-based Reaction Rate e-module is presented as follows:

Table 5. Design of the STEM-Integrated PBL E-Module on the Reaction Rate Topic

No	Component	Overview
1	Front Cover	
2	E-Module Contents	
3	Back Cover	

Analysis of E-Module Validation Results

The validation process was conducted to assess two main aspects: the material aspect and the media aspect. Validation of the material aspect included three evaluation components, namely content feasibility, presentation feasibility, and contextual assessment. The validation results of the STEM integrated Problem Based Learning

(PBL) e-module on the *Reaction Rate* topic indicate that the e-module is highly feasible across various aspects.

For the content feasibility aspect, which includes six indicators material coverage, accuracy, currency, curiosity stimulation, PBL implementation, and STEM integration the three lecturer validators gave scores of D1: 94%, D2: 81%, and D3: 89%, while the four teacher validators gave scores of G1: 90%, G2: 94%, G3: 87%, and G4: 89%. The overall average was 89.3%, falling into the very feasible category, indicating that the e-module content is accurate, relevant, and aligned with PBL-STEM principles. The analysis of the content feasibility validation results for the STEM integrated Problem Based Learning (PBL) e-module on the *Reaction Rate* topic is presented in Figure 2.

Figure 2. Graph of the Content Feasibility Analysis Results of the E-Module

For the presentation feasibility aspect, evaluated based on four indicators presentation techniques, presentation aids, learning delivery, and coherence and logical flow the lecturer validators scored D1: 88%, D2: 85%, D3: 85%, and the teacher validators scored G1: 90%, G2: 96%, G3: 88%, G4: 88%, yielding an overall average of 88.7%. This shows that the e-module presentation is systematic, engaging, and easy for students to understand. The analysis of the presentation feasibility validation results for the STEM integrated Problem Based Learning (PBL) e-module on the Reaction Rate topic is presented in Figure 3.

Figure 3. Graph of the Presentation Feasibility Analysis Results of the E-Module

Regarding the contextual assessment aspect, which evaluates the contextual relevance and components, the lecturer validators gave scores of D1: 92%, D2: 78%, D3:

86%, and the teacher validators gave G1: 89%, G2: 97%, G3: 89%, G4: 92%, resulting in an overall average of 88.9%, categorized as very feasible. This indicates that the e-module effectively connects reaction rate concepts with relevant real life contextual phenomena. The analysis of the contextual feasibility validation results for the STEM integrated Problem Based Learning (PBL) e-module on the Reaction Rate topic is presented in Figure 4.

Figure 4. Graph of the Contextual Assessment Analysis Results of the E-Module

Meanwhile, the media aspect validation was conducted by assessing three main components: graphic feasibility, language feasibility, and presentation or accessibility. In the graphic feasibility aspect, which includes the e-module size, cover design, and content layout, the three lecturer validators gave scores of D1: 86.2%, D2: 77.6%, D3: 90.5%, while the four teacher validators gave G1: 87.1%, G2: 89.7%, G3: 90.5%, G4: 87.9%, resulting in an overall average of 87.1%, categorized as very feasible. This indicates that the e-module's visual appearance is proportional and aesthetically appealing. The analysis of the graphic feasibility validation results is presented in Figure 5.

Figure 5. Graph of the Graphic Feasibility Analysis Results of the E-Module

For the language feasibility aspect, which assesses clarity, communicativeness, dialogical style, suitability for learners, grammatical accuracy, and use of terms and symbols, the lecturer validators scored D1: 87.5%, D2: 75%, D3: 91.7%, and the teacher validators scored G1: 83.3%, G2: 91.7%, G3: 91.7%, G4: 89.6%, with an overall average of 87.2%, also categorized as very feasible. This shows that the language used in the e-

module aligns with student characteristics and effectively supports learning communication. The analysis of the language feasibility results is presented in Figure 6.

Figure 6. Graph of the Language Feasibility Analysis Results of the E-Module

In the presentation/accessibility aspect, which evaluates display accessibility, user navigation, layout consistency, loading speed, and suitability of interactive media, the lecturer validators scored D1: 95%, D2: 75%, D3: 90%, and the teacher validators scored G1: 90%, G2: 95%, G3: 95%, G4: 90%, yielding an overall average of 90%, categorized as very feasible. This indicates that the e-module is easy to access, interactive, and responsive to user needs. The analysis of the presentation/accessibility validation results is presented in Figure 7.

Figure 7. Graph of the Presentation/Accessibility Analysis Results of the E-Module

The results of the feasibility analysis conducted by material and media experts on the PBL (Problem Based Learning) STEM-integrated Reaction Rate E-Module are tabulated to show the level of feasibility of the developed product. A summary of the evaluation results is presented in Table 6 and Table 7.

Table 6. Analysis of Material Expert Validation Results

Aspect	Feasibility Percentage (%)							Average Score (%)
	D1	D2	D3	G1	G2	G3	G4	
Content Feasibility Aspect	94.0%	81.0%	89.3%	90.5%	94.0%	86.9%	89.3%	89.3%
Presentation Feasibility Aspect	88.5%	84.6%	84.6%	90.4%	96.2%	88.5%	88.5%	88.7%
Contextual Assessment	91.7%	77.8%	86.1%	88.9%	97.2%	88.9%	91.7%	88.9%
Total Score								**89.0**
Criteria								**Very Valid**

Table 7. Analysis of Media Expert Validation Results

Aspect	Feasibility Percentage (%)							Average Score (%)
	D1	D2	D3	G1	G2	G3	G4	
Graphic Feasibility Aspect	86.2%	77.6%	90.5%	87.1%	89.7%	90.5%	87.9%	87.1%
Language Feasibility Aspect	87.5%	75.0%	91.7%	83.3%	91.7%	91.7%	89.6%	87.2%
Presentation/ Accessibility	95.0%	75.0%	90.0%	90.0%	95.0%	95.0%	90.0%	90.0%
Total Score								**87.4**
Criteria								**Very Valid**

Based on the validation results obtained from seven validators, the PBL-STEM–based e-module developed in this study achieved a feasibility percentage of 89.0% for the material aspect and 87.4% for the media aspect. Both percentages fall into the *very valid* category, indicating that the e-module meets the content and presentation eligibility criteria in accordance with BSNP standards and is feasible for implementation in chemistry learning. These high validation scores demonstrate that the e-module is able to present material accurately, systematically, and attractively, while also supporting learning activities that position students as active participants in constructing their understanding through contextual problem situations.

These findings are consistent with the study conducted by (Dibyantini & Sulastri, 2023), which reported that their problem-based e-module on the reaction rate topic also met BSNP eligibility standards, obtaining scores of 3.69 for content feasibility, 3.7 for language feasibility, 3.62 for presentation feasibility, and 3.78 for graphical feasibility, all of which fall into the valid category without requiring revision. The alignment between the two studies indicates a consistent trend showing that the development of problem based e-modules, both in this research and in previous work, has successfully produces

instructional materials that are feasible, valid, and effective in supporting more meaningful chemistry learning. The implementation of contextual learning provides a real and meaningful learning experience, as students can understand the connection between the lesson material and everyday life (Lie, 2022). According to Anissa & Lutfi (2024), the application of a contextual approach in learning plays an important role in helping students understand the material more deeply. Students are encouraged to connect the concepts they learn with experiences and events that occur in their daily lives.

CONCLUSION

The conclusion of this study on the development of a STEM-integrated Problem-Based Learning (PBL) e-module on the Reaction Rate topic indicates that the developed product has been validated by seven validators. The material aspect, including content feasibility, presentation, and contextual feasibility, received an average score of 89.0%, categorized as very valid. The media aspect, including graphics, language, and presentation/accessibility, obtained an average score of 87.4%, also categorized as very valid. These findings demonstrate that the STEM-integrated PBL e-module meets the feasibility criteria in terms of both content and media. Furthermore, this study provides a scientific contribution by producing a digital learning resource that comprehensively integrates STEM and PBL approaches, supporting more contextual chemistry learning oriented toward 21st-century skills. However, the study has limitations, as it only covers the development and validation stages without directly testing the module's effectiveness in classroom settings. Based on these limitations, further research is recommended to conduct field trials on a larger scale to evaluate the e-module's impact on students' conceptual understanding, problem-solving skills, and attitudes toward PBL-STEM learning.

REFERENCES

Anissa, A. S., & Lutfi. (2024). Meningkatkan Kemampuan Peserta Didik Menghubungkan Materi dalam Kehidupan Sehari-hari dengan Strategy Concept Attainment, Pendekatan Kontekstual, dan Metode Demokrasi. *Seminar Nasional Dan Publikasi Ilmiah FIP UMJ*, *2022*, 468–477.

Aulya, Raisha Amayati Asyhar, R., & Yusnaidar. (2021). Pengembangan E-Modul Kimia Berbasis PjBL-STEM untuk Pembelajaran Daring Siswa SMA pada Materi Larutan Penyangga. *Journal of The Indonesian Society of Integrated Chemistry*, *13*(2), 84–91.

Chalim, S., & Anwas, E. O. M. (2018). Peran Orangtua dan Guru dalam Membangun Internet sebagai Sumber Pembelajaran. *Jurnal Penyuluhan*, *14*(1), 33–42. https://doi.org/10.25015/penyuluhan.v14i1.19558

Dalimunthe, M., Sugiharti, G., Amdayani, S., & Siregar, M. I. (2025). The Effectiveness of STEM-Based Electrochemistry E-Modules in Enhancing Critical Thinking Skills. *Jurnal Pendidikan Dan Pembelajaran Kimia*, *14*(1), 70–76. https://doi.org/10.23960/jppk.v14.i1.32718

Dibyantini, R. E., Amdayani, S., Siregar, M. I., & Syafriani, D. (2023). Application of STEM-PjBL Based Chemistry Module to Improve Science Literacy and Student Learning Motivation. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 95–102. https://doi.org/10.29303/jppipa.v9ispecialissue.5872

Dibyantini, R. E., & Sulastri. (2023). Pengembangan bahan ajar e-modul berbasis

masalah terhadap kemampuan berpikir kritis siswa pada materi laju reaksi. *Educenter : Jurnal Ilmiah Pendidikan*, *2*(3), 337–342. https://doi.org/10.55904/educenter.v2i3.196

Fadila, R. D., Meriza, N., Yolida, B., & Marpaung, R. R. T. (2025). The Effect of STEM Integrated PjBL Learning on Students' HOTS and Collaboration Abilities on Biotechnology Material. *Jurnal Pendidikan Dan Pembelajaran Kimia*, *14*(1), 20–29. https://doi.org/10.23960/jppk.v14.i1.32403

Isma, A., Isma, A., Isma, A., & Isma, A. (2023). Peta Permasalahan Pendidikan Abad 21 di Indonesia. *Jurnal Pendidikan Terapan*, *01*(September), 11–28. https://doi.org/10.61255/jupiter.v1i3.153

Lee, H. C., & Blanchard, M. R. (2019). Why teach with PBL? Motivational factors underlying middle and high school teachers' use of problem-based learning. *Interdisciplinary Journal of Problem-Based Learning*, *13*(1). https://doi.org/10.7771/1541-5015.1719

Lestari, D. A. B., Astuti, B., & Darsono, T. (2018). Implementasi LKS Dengan Pendekatan STEM (Science, Technology, Engineering, And Mathematics) Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa. *Jurnal Pendidikan Fisika Dan Teknologi*, *4*(2), 202–207. https://doi.org/10.29303/jpft.v4i2.809

Lie, R. (2022). Model Pembelajaran Kontekstual (Contextual Teaching Learning) Pada Pelajaran PAI Sebagai Salah Satu Inovasi Pengembangan Kurikulum di Sekolah. *Edugama: Jurnal Kependidikan Dan Sosial Keagamaan*, *8*(2), 258–269. https://doi.org/10.32923/edugama.v8i2.2590

Mardhiyah, R. H., Aldriani, S. N. F., Febyana, C., & Zulfikar, M. R. (2021). *Pentingnya Keterampilan Belajar di Abad 21 sebagai Tuntutan dalam Pengembangan Sumber Daya Manusia*. *12*(1), 29–40.

Munawaroh, M., Marlina, L., & Sholeh, M. I. (2022). Pengembangan Bahan Ajar E-Modul Kimia Pada Materi Reaksi Redoks Berbasis Problem Based Learning (PBL) Menggunakan Aplikasi Flip Pdf Professional. *Jurnal Al'ilmi*, *11*(1), 20–24.

Rachmawati, D., Suhery, T., & Anom, K. (2017). Pengembangan Bahan Ajar Kimia Dasar Berbasis Stem Problem Based Learning Pada Materi Termodinamika Untuk Mahasiswa Program Studi Pendidikan. *Prosiding Seminar Nasional Pendidikan IPA 2017*, 239–248.

Solihin, L., Utama, B., Pratiwi, I., & Novirina. (2019). Indeks Aktivitas Literasi Membaca 34 Provinsi. In *Pusat Penelitian Kebijakan Pendidikan dan Kebudayaan, Badan Penelitian dan Pengembangan, Kementerian Pendidikan dan Kebudayaan* (Issue 2).

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional Development for Training Teachers of Exceptional Children A Sourcebook.* Bloomington, Indiana: Leadership Training Institute/Special Education, University of Minnesota.

Warman, E. (2025). Pengembangan Bahan Ajar Bahasa Indonesia untuk Pembelajaran Membaca di Sekolah Dasar. *Dinamika: Jurnal Bahasa, Sastra, Dan Pembelajarannya*, *8*(1), 107–126.