JoSSEd
Journal of Science and Science Education
ISSN: 2774-1869 eISSN: 2774-2105

Development of a Problem-Based Learning E-Module on Reaction Rates for Phase F Students (SMA/MA)

Rizka Sofia Irawan[1*], Dedy Suhendra[2], Saprizal Hadisaputra[3]

[1] Magister of Science Education, Postgraduate Program, University of Mataram, Lombok, Indonesia.
[2] Department of Chemistry, University of Mataram, Lombok, Indonesia.
[3] Department of Chemistry Education, University of Mataram, Lombok, Indonesia.

Received: July 1, 2026
Revised: October 12, 2026
Accepted: October 26, 2026
Published: October 31, 2026

Corresponding Author:
Rizka Sofia Irawan
sofhiairawan@gmail.com

DOI: 10.29303/jossed.v7i2.15907

Open Access

© 2026 he Authors. This article is distributed under a (CC-BY License)

Abstract: Reaction rates are considered a difficult chemistry topic because of their abstract concepts and students' tendency to rely on memorization. Problem-Based Learning (PBL) can provide an active and contextual learning experience, while e-modules can support systematic, interactive, and flexible learning. However, e-modules that systematically integrate PBL stages for teaching reaction rates remain limited. Therefore, this study aimed to develop a valid PBL-based e-module on reaction rates for chemistry learning. This study employed the 4D development model, consisting of Define, Design, Develop, and Disseminate stages; however, the study was limited to the Define, Design, and Develop stages. The developed learning materials included a Learning Objectives Sequence (ATP), teaching module, e-module, and student worksheet (LKPD). The validity of the learning materials was assessed by three expert validators using Aiken's V index. The results showed that the ATP obtained Aiken's V values ranging from 0.77 to 0.94, the teaching module from 0.88 to 0.91, the e-module from 0.81 to 0.94, and the LKPD from 0.86 to 0.91. The assessed aspects of presentation, content, and language were categorized as valid to highly valid. Based on the validation results and revisions based on expert feedback, the developed PBL-based reaction rate e-module and its supporting learning materials were considered valid and suitable for use in chemistry learning. Further research is needed to examine their practicality and effectiveness in classroom implementation.

Keywords: Chemistry learning; E-module; Problem-Based Learning; Reaction rate

Introduction

Reaction rate is one of the chemistry topics that students find difficult to understand because of its abstract concepts, complexity, and potential to cause misconceptions (Norhidayah, 2024; Latif et al., 2026). These difficulties are reflected in students' limited ability to explain reaction rate concepts, identify factors affecting reaction rates, and apply conceptual understanding to problem-solving (Hasbi & Fitri, 2026). Furthermore, memorization-oriented learning may limit the development of students' thinking skills (Sumartini, 2022). Therefore, an active learning model that encourages conceptual understanding and problem-solving, such as Problem-Based Learning (PBL), is needed.

Problem-Based Learning (PBL) provides opportunities for students to actively engage in identifying problems, gathering information, conducting investigations, and drawing conclusions (Alfita et al., 2025). This approach promotes meaningful conceptual understanding and student engagement in the learning process (Anggraini et al., 2024; Mahmudi & Arief, 2025). Its implementation in reaction rate learning is expected to provide contextual learning experiences and facilitate deeper understanding of abstract chemical concepts (Aisyah et al., 2025). However, the effectiveness of PBL can be further supported by appropriate teaching materials, particularly electronic modules (e-modules).

E-modules provide systematic, interactive, and flexible learning materials that integrate various multimedia components, including text, images, videos, and animations, to facilitate students' understanding of abstract concepts (Mutia et al., 2025; Nababan & Zega, 2024). These features can improve learning motivation, support independent learning, and provide accessible learning resources anytime and anywhere (Mandayanti & Rusdi, 2026; Munir et al., 2024; Maharani, 2025). Furthermore, e-modules can integrate learning materials and activities into a structured resource, making them suitable for supporting the implementation of PBL (Violadini & Mustika, 2021).

How to Cite:
Irawan, R. S., Suhendra, D., & Hadisaputra, S. H. (2026). Development of a Problem-Based Learning E-Module on Reaction Rates for Phase F Students (SMA/MA). *Journal of Science and Science Education*, *7*(2), 116–124. https://doi.org/10.29303/jossed.v7i2.15907

Previous studies have demonstrated the potential of PBL in promoting active learning and problem-solving skills (Husna et al., 2025; Stevana et al., 2025), while e-modules have been shown to facilitate systematic and interactive learning through multimedia integration (April et al., 2025; Hurrahman et al., 2022). However, research specifically integrating PBL syntax into e-modules for teaching reaction rates remains limited. This research gap highlights the need to develop a PBL-based reaction rate e-module that systematically guides students through problem identification, investigation, solution development, and evaluation. Therefore, this study aims to develop a Problem-Based Learning e-module on reaction rates that is suitable for use in chemistry learning.

Method

The development model used in this study was the 4D model (Define, Design, Develop, and Disseminate) developed by Thiagarajan. In this study, the 4D model was implemented through three stages: Define, Design, and Develop. The Define stage was conducted to identify and determine learning needs through an initial analysis, including an analysis of learning problems in chemistry education at the school, an analysis of student characteristics, an analysis of the reaction rate material, a task analysis, and an analysis of learning objectives based on the Chemistry Learning Outcomes (CP) for Phase F. The Design stage involved designing a Problem-Based Learning (PBL) e-module on reaction rates, including the development of the e-module framework, determination of the format for presenting the learning materials, design of student worksheets (LKPD), preparation of research instruments, and integration of the PBL syntax into the learning activities within the e-module. The Develop stage was conducted to produce a product that met the validity criteria through validation by expert validators and product revisions based on the suggestions and feedback provided by the validators.

Research Instruments

The research instruments used in this study included a validation sheet used to assess the validity of the developed e-module, as well as other assessment instruments, including the Learning Objective Flow (ATP), teaching module, and student worksheets (LKPD).

Data Analysis Techniques

The validity of the e-module and other research instruments was analyzed using Aiken's V index, with Formula 1.

$$V = \frac{\sum s}{[n(c-1)]} \quad (1)$$

Description:
s = r – Lo
n = number of experts/respondents
Lo = lowest validity rating score
c = highest validity rating score
r = score given by the expert/respondent

The results of the analysis were then classified into Aiken's validity categories, as presented in Table 1.

Table 1. Aikens's Validity Categories

Index	Category
≤0,39	Lessvalid
0,40-0,79	Valid
0,80-1,00	Highly valid

Result and Discussion

The development of the e-module using the PBL model for the topic of reaction rates was conducted using the 4D development model (Define, Design, Develop, and Disseminate). However, this study was limited to three stages: Define, Design, and Develop.

Define Stage

The define stage was conducted to identify field conditions, learning problems, and students' needs as the basis for developing teaching materials (Maruwu, 2024; Utami, 2023). The analysis revealed that SMAN 1 Lembar had implemented the Merdeka Curriculum, with reaction rates taught in Phase F; however, chemistry learning remained dominated by printed textbooks, while the utilization of digital technology was not optimal. Teacher interviews and student analysis indicated that reaction rates were difficult to understand due to their abstract concepts, highlighting the need for systematic, engaging, and digitally accessible teaching materials. Furthermore, concept analysis based on Learning Outcomes (CP) and the Learning Objectives Sequence (ATP) identified the main content, including reaction rates, collision theory, activation energy, and factors affecting reaction rates. Task analysis was then conducted by integrating the five stages of the Problem-Based Learning (PBL) model into the learning activities, namely problem orientation, learning organization, individual and group investigations, development and presentation of work, and analysis and evaluation of the problem-solving process. These findings were subsequently used to formulate the learning objectives and establish the foundation for developing a PBL-based reaction rate e-module.

Design Result

The design stage produced an initial PBL-based reaction rate e-module developed using Canva and structured according to the predetermined Learning

Objectives Sequence (ATP). The e-module comprised learning objectives, a concept map, reaction rate materials, images, animations, practical video demonstrations, worksheets (LKPD), a glossary, learning evaluation activities, and references. The learning activities were systematically organized according to the five stages of the PBL model: orienting students to the problem, organizing students for learning, guiding investigations, developing and presenting the work, and analyzing and evaluating the problem-solving process. Each component was designed to support students' conceptual understanding, active participation, and independent learning.

The completed e-module design was subsequently converted into a Heyzine Flipbook to provide an interactive digital learning resource. This format enabled the integration of multimedia elements, hyperlinks, and interactive navigation to support students' understanding of reaction rate concepts and facilitate more engaging learning experiences. Furthermore, the digital format allowed students to access learning materials more flexibly through electronic devices. The initial product was then prepared for the expert validation stage to evaluate its suitability in terms of content, presentation, and language before further revision and implementation. The appearance of the developed e-module is presented in Figure 1.

Development Result

This development stage involved refining the initial draft of the reaction rate e-module based on the PBL model. The developed product was subsequently validated by three expert validators specializing in subject matter and media. The validation results and feedback provided by the validators were used as the basis for revising and improving the developed product. The materials and instruments subjected to validation included ATP, teaching module, e-module, and LKPD. The results of the product development are presented in Table 2.



Figure 1. Interface of the PBL-Based Reaction Rate E-Module

Table 2. The results of the Product Development

Product	Characteristics Developed
ATP	Students are expected to understand, analyze, and evaluate the concepts of reaction rates, collision theory, and the factors affecting reaction rates through problem-based learning activities, discussions, and experiments. Through group-based practical activities, students are also expected to design, conduct, and evaluate simple experiments to develop their science process skills and critical thinking skills in understanding chemical phenomena in everyday life.
Teaching Module	Designed based on the Problem-Based Learning model and integrating indicators of science process skills and critical thinking skills.
E-Module	An electronic module on reaction rates developed based on the Problem-Based Learning model and integrating science process skills and critical thinking skills. The e-module contains text, images, and videos and is equipped with worksheets that students can complete and submit directly through the provided links.
Student Worksheet (LKPD)	A student worksheet developed based on the Problem-Based Learning model and integrating science process skills and critical thinking skills.

Table 2 shows that the developed learning products consist of an ATP, teaching module, e-module, and LKPD, all of which were designed based on the PBL model. The PBL model uses problems as the starting point for learning and encourages students to actively engage in investigation, discussion, and the development of problem-solving skills (Wardani, 2023; Aziza et al., 2025). As the main product, the e-module

was developed by incorporating various multimedia elements, such as text, images, videos, and interactive student worksheets, to support the learning process. The use of electronic learning materials that integrate various forms of media can facilitate more interactive content presentation and support student engagement in the learning process (Baroroh et al., 2024; Rahmawati et al., 2025). The developed learning materials were subsequently validated by experts to determine their validity and obtain feedback as a basis for further improvement.

Expert Validation Results

The expert validation stage was conducted to determine the validity and suitability of developed learning materials before they were used in the trial stage (Fernandes & Syarifuddin, 2020). The validation was carried out by three experts with relevant expertise in their respective fields. The validation results for the learning materials are presented below.

Validity of the ATP

The results of the validity analysis of the Learning Objectives and Achievement Pathway (ATP) using Aiken's V formula are presented in Table 3.

Table 3. ATP Validation Results

Aspects Assessed	Aiken's V Value	Category
Format	0.94	Highly Valid
Content	0.77	Valid
Language	0.83	Highly Valid

The validation results presented in Table 3 indicate that the content aspect of the ATP was categorized as valid (0.40–0.79), while the other aspects achieved a very valid category (0.80–1.00). These findings demonstrate that the ATP had an appropriate structure, content, and language to support learning objectives. However, the validators recommended several improvements, including completing the Phase F Learning Outcomes (CP), specifying relevant Pancasila Student Profile elements, aligning learning objectives with the appropriate taxonomy, adding a specific column for Science Process Skills (SPS) and Critical Thinking Skills (CTS), and reviewing the relevance of the reaction mechanism subtopic. Accordingly, the ATP was revised by incorporating these suggestions and removing the reaction mechanism subtopic to ensure alignment with the scope of senior high school chemistry content.

These findings are consistent with the Constructive Alignment concept proposed by Biggs and Tang (2011), which emphasizes alignment among learning objectives, learning activities, and assessments. Similar findings were reported by Astutik (2024) and Aulina (2026), who demonstrated that validated ATP documents achieved very valid categories. The lower validity score in the content aspect indicates the need for refinement to ensure that learning outcomes, objectives, materials, and targeted competencies are appropriately aligned. Expert feedback therefore played an important role in improving the quality and consistency of the ATP as the foundation for developing the teaching module. After the revisions were completed, the teaching module proceeded to the expert validation stage.

.

Teaching Module Validity

The results of the teaching module validity analysis are presented in Table 4.

Table 4. Results of Teaching Module Validation

Observed Aspect	Aiken's V Value	Category
Presentation	0.89	Highly Valid
Content	0.88	Highly Valid
Language	0.91	Highly Valid

The validation results presented in Table 4 indicate that the developed teaching module achieved a highly valid category across all assessed aspects, with validity scores ranging from 0.80 to 1.00. These findings demonstrate that the module met the validity criteria in terms of presentation, content, and language and was suitable for use following revisions based on expert feedback. Similar findings were reported by Septiana et al. (2025), who obtained validity scores of 0.88 for material and 0.90 for media, and Khoirunnisa et al. (2024), with scores of 0.91 and 0.92, respectively, indicating that systematically designed PBL-based teaching modules can meet established validity criteria. Based on the validators' suggestions, three main revisions were implemented: adding learning activities to support Science Process Skills (SPS) and Critical Thinking Skills (CTS), providing a more detailed instructional time allocation for the third meeting, and revising the learning objectives using the ABCD format (Audience, Behavior, Condition, and Degree).

The revision of learning objectives using the ABCD format aimed to ensure that the expected competencies were specific, observable, and measurable. This approach clarifies the target learners, expected behaviors, learning conditions, and achievement criteria, thereby facilitating the alignment of instructional activities and assessments with learning outcomes (Ramdhan & Hakin, 2025). Furthermore, the improvement of learning activities was intended to provide students with opportunities to develop SPS and CTS beyond conceptual understanding.

The more detailed time allocation was intended to ensure that each learning activity could be implemented systematically and effectively. Overall, the revisions based on expert feedback improved the quality of the teaching module and strengthened the alignment among learning objectives, instructional activities, and assessment processes.

E-Module Validity

The results of the e-module validity assessment are presented in Table 5.

Table 5. Results of the E-Module Validation

Observed Aspect	Aiken's V Value	Category
Presentation	0.81	Highly Valid
Content	0.94	Highly Valid
Language	0.83	Highly Valid

Table 5 shows that the e-module validation results for all assessed aspects were categorized as highly valid, with Aiken's V values ranging from 0.80 to 1.00. These results indicate that the e-module meets the required criteria in terms of content appropriateness, systematic presentation, and language use, making it suitable for use as a Chemistry teaching material. High-quality teaching materials should meet the criteria of content, presentation, and language appropriateness to support their effective use in the learning process (Gustiar et al., 2023). The high validation results obtained in this study are also consistent with the findings of Susanti and Sholihah (2021), who reported an e-module validation score of 0.94, categorized as highly valid. Similar findings were reported by Ellysia and Irfan (2021), who obtained a validity score of 0.96, also categorized as highly valid, after the e-module underwent a validation process and revisions based on the validators' suggestions.

The e-module developed in this study was also revised based on the validators' feedback. The revisions included correcting and completing the excerpts of the Learning Outcomes (CP) in accordance with the provisions of the BKSAP, ensuring consistent use of the term "students" in the Learning Objectives (TP), adding hyperlinks to the concept map that connect each section to the corresponding learning materials, and clarifying the required outputs for the presentation of students' work, including reports and presentations of discussion results. The e-module was also supplemented with an author biography, while its writing conventions and language use were revised to conform to standard Indonesian language rules. In addition, the illustration depicting a car collision was revised to ensure its relevance to the learning context. These revisions were undertaken to improve the e-module so that it would be more systematic, communicative, and aligned with students' learning needs (Anggraini & Susanti, 2025).

Validity of the Student Worksheet (LKPD)

The results of the LKPD validity analysis are presented in Table 6.

Table 6. Results of LKPD Validation

Observed Aspect	Aiken's V Value	Category
Presentation	0.86	Highly Valid
Content	0.91	Highly Valid
Language	0.91	Highly Valid

The validation results presented in Table 6 indicate that all aspects of the LKPD achieved a highly valid category, with Aiken's V values ranging from 0.80 to 1.00, demonstrating its suitability in terms of content, presentation, and language. These findings are consistent with Rembet et al. (2026), who reported feasibility percentages of 92% for material and 96% for media, and Dikta et al. (2022), who classified the developed LKPD as valid based on CVR and CVI values of 1. Revisions were subsequently made based on expert feedback, including aligning the LKPD content with the third meeting's learning objectives and improving the illustrations in Figures 1 and 2 to distinguish more clearly between the effects of concentration and reaction rate, thereby minimizing potential misconceptions. These revisions enhanced the clarity, accuracy, and alignment of the LKPD with the intended learning objectives without changing its main content (Puspitasari et al., 2025).

Conclusions

This study successfully developed a Problem-Based Learning (PBL)-based e-module on reaction rates using the Define, Design, and Develop stages of the 4D development model. The learning materials, consisting of an ATP, teaching module, e-module, and student worksheet (LKPD), integrated PBL syntax with Science Process Skills (SPS) and Critical Thinking Skills (CTS), supported by multimedia and interactive learning activities. Expert validation results demonstrated that all developed materials met the validity criteria, with Aiken's V values ranging from 0.77 to 0.94 for ATP, 0.88 to 0.91 for the teaching module, 0.81 to 0.94 for the e-module, and 0.86 to 0.91 for LKPD. Revisions based on expert feedback further improved the quality and alignment of the learning materials. Therefore, the developed PBL-based reaction rate e-module is considered valid and suitable for use as a chemistry learning resource, although further research is required to evaluate its practicality and effectiveness in classroom implementation.

Acknowledgments

The authors would like to express their sincere gratitude to all those who contributed to the completion of this study, particularly the supervisors for their guidance, valuable suggestions, and support throughout the research process. The authors also extend their appreciation to the school, teachers, and students who participated in this study and provided valuable assistance during the implementation of the research. Special appreciation is also extended to all validators and colleagues who provided constructive feedback to support the improvement of the developed electronic module.

Author Contributions

Conceptualization, RSI, DS, and SH; methodology, RSI, DS, and SH; validation, SH; formal analysis, RSI, DS, and SH;

investigation, RSI; data curation, RSI, DS, and SH; writing-original draft preparation, RSI; writing-review and editing, RSI, DS, and SH; visualization, RSI, DS, and SH. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding

Conflicts of Interest
The authors declare that they have no conflict of interest.

References

Munir, S., Pratikto, H., & Rahayu, W. P. (2024). Merdeka Belajar, Merdeka Berkarya: E-Modul Android untuk Mendukung Implementasi Kurikulum Merdeka. Research and Development Journal of Education, 10(1), 617-627. http://dx.doi.org/10.30998/rdje.v10i1.23584

Ramdhan, T. W., & Hakim, Z. (2025). Desain dan perencanaan pembelajaran. Press STAI Darul Hikmah Bangkalan, 1(1), 1-203.

Nababan, K., & Zega, R. S. (2024). Pengembangan E-Modul Laju Reaksi Discovery Learning Berbasis Blog untuk Meningkatkan Motivasi Belajar dan Komunikasi Siswa: Analisis Kebutuhan. Oxygenius: *Journal Of Chemistry,* 6(1), 14-22. https://doi.org/10.37033/ojce.v6i1.638

Hurrahman, M., Erlina, E., Melati, H. A., Enawaty, E., & Sartika, R. P. (2022). Pengembangan E-Modul Berbasis Multipel Representasi dengan Bantuan Teknologi Augmented Reality untuk Pembelajaran Materi Bentuk Molekul. *Jurnal Pendidikan Sains Indonesia,* 10(1), 89-114. https://doi.org/10.24815/jpsi.v10i1.22579

Mutia, T., Suharto, Y., Sahrina, A., Wahyudi, A., Atmaja, M. A. R., & Aprilia, R. (2025). Efektivitas E-Modul Interaktif Berbasis Project Based Learning Terhadap Kemampuan Berfikir Kreatif Siswa. Geodika*: Jurnal Kajian Ilmu dan Pendidikan Geografi*, 9(1), 42-51. https://doi.org/10.29408/geodika.v9i1.28193

Aisyah, S. N., Sihaloho, M., Tanggio, J. S., Lukum, A., & Munandar, H. (2025). Pengaruh Model Pembelajaran Problem Based Learning terhadap Hasil Belajar Siswa pada Materi Laju Reaksi. *Jurnal Entropi,* 20(1), 44-51. https://doi.org/10.37905/je.v20i1.32546

Mahmudi, M. B., & Arief, A. (2025). Strategi Joyful Learning dalam Meningkatkan Motivasi, Keterlibatan dan Pemahaman Konsep Peserta Didik pada Pembelajaran Pendidikan Agama Islam. QOSIM: *Jurnal Pendidikan Sosial & Humaniora,* 3(1), 96-103. https://doi.org/10.61104/jq.v3i1.662

Maharani, A. (2025). Pemanfaatan Pengembangan E-Modul IPA Interaktif Berbasis Android untuk Siswa SMP. *Journal Sains and Education*, 3(1), 24-30.

Husna, A., Ilmi, N., & Gusmaneli, G. (2025). Strategi Pembelajaran Berbasis Masalah dalam Meningkatkan Kemampuan Berpikir Kritis Peserta Didik. Katalis Pendidikan: *Jurnal Ilmu Pendidikan dan Matematika*, 2(2), 76-86. https://doi.org/10.62383/katalis.v2i2.1532

Dikta, P. G. A. (2022). Validitas pengembangan LKPD IPA berorientasi tri hita karana pada kelas V sekolah dasar. Jurnal Pendidikan Fisika Undiksha, 12(1), 154-163.

Violadini, R., & Mustika, D. (2021). Pengembangan e-modul berbasis metode inkuiri pada pembelajaran tematik di sekolah dasar. Jurnal basicedu, 5(3), 1210-1222. https://doi.org/10.31004/basicedu.v5i3.899

April, N. D. R., Anggraini, F. W., Kelen, R. P., & Setiadi, H. W. (2025). E-Modul Analisis Pemnfaatan E-Modul Interaktif dalam Meningkatkan Kemandirian Belajar Siswa Sekolah Dasar. Didaktik: *Jurnal Ilmiah PGSD STKIP Subang*, 11(4), 320-334. https://doi.org/10.36989/didaktik.v11i04.9125

Stevana, R., Selarista, S., & Indra, I. (2025). Penerapan dan Karakteristik Model Pembelajaran Berbasis Masalah Serta Pengaruhnya terhadap Kemampuan Pemecahan Masalah dan Berpikir Kritis Siswa. Nubuat: *Jurnal Pendidikan Agama Kristen dan Katolik,* 2(4), 153-164. https://doi.org/10.61132/nubuat.v2i4.1601

Mandayanti, S., & Rusdi, H. (2026, May). Analisis Kebutuhan Pengembangan E-Modul Biologi Berbasis Media Interaktif pada Pembelajaran Daring di SMP. *In Prosiding Seminar Nasional FKIP Universitas Muslim Maros,* 3(1), 26-32. https://ejournals.umma.ac.id/index.php/semnas/article/view/3349

Alfita, N. A., Harianto, D., Ramadhani, N., Wahid, A., Sukri, M. A., & Fahlan, M. F. (2025). Efektivitas Strategi Pembelajaran Berbasis Masalah dalam Meningkatkan Kemampuan Berfikir Siswa. *Contemporary Education Review*, 1(1), 10-19. https://doi.org/10.69875/cer.v1i1.297

Anggraini, P. N., Aprima, D., & Siligar, E. P. (2024). Penerapan Model *Problem Based Learning* Berbantuan Media Konkrit Terhadap Kemampuan Pemahaman Konsep IPA Siswa Kelas V SD. *Journal of Education Research*, 5(4), 4547-4562. https://doi.org/10.37985/jer.v5i4.1605

Astutik, F. I. (2024). Pengembangan Perangkat Pembelajaran Berbasis Saintifik untuk Siswa Sekolah Dasar. Mitra PGMI: Jurnal Kependidikan MI, 10(1), 96-115. https://doi.org/10.46963/mpgmi.v10i1.1612

Sumartini, T. S. (2022). Pengaruh Habit of Mind Terhadap Kemampuan Berpikir Kreatif Matematis Melalui Metode Pembelajaran Improve. Mosharafa: *Jurnal Pendidikan Matematik*a, 11(1), 167-178. https://doi.org/10.31980/mosharafa.v11i1.696

Hasbi, M., & Fitri, F. (2026). Bimbingan Belajar Penggunaan Konsep Laju Reaksi (Matematika) untuk Memahami Proses Metabolisme dalam Biologi Tingkat SMA. *Jurnal Pengabdian Kepada Masyarakat Patikala,* 5(3), 3949–3959. https://doi.org/10.51574/patikala.v5i3.4210

Latif, H., Laliyo, L. A. R., & Kurniawati, E. (2026). Analisis Kualitas Instrumen Tes Untuk Mengukur Pemahaman Konsep Siswa Pada Materi Laju Reaksi Dengan Pemodelan Rasch. *Jurnal Entropi*, *21*(1), 1-5. https://doi.org/10.37905/je.v21i1.36133

Wardani, D. A. W. (2023). Problem based learning: membuka peluang kolaborasi dan pengembangan skill siswa. Jawa Dwipa, 4(1), 1-17.

Baroroh, A. Z., Kusumastuti, D. A., & Kamal, R. (2024). Pemanfaatan teknologi dalam pembelajaran. Perspektif: Jurnal Pendidikan dan Ilmu Bahasa, 2(4), 269-286. https://doi.org/10.59059/perspektif.v2i4.1952

Rahmawati, L., Bachri, B. S., & Maureen, I. Y. (2025). Kajian Literatur: Pengaruh E-Modul Interaktif Terhadap Motivasi Siswa dalam Pembelajaran. Paedagogie, 20(2), 47-58. https://doi.org/10.31603/paedagogie.v20i2.14025

Norhidayah, N. (2024). Reduksi Miskonsepsi pada Materi Laju Reaksi Kimia dengan Model Pembelajaran POGIL. Al Washliyah: *Jurnal Penelitian Sosial dan Humaniora,* 2(1), 17-22. https://doi.org/10.70943/jsh.v2i1.73

Aziza, R. S., Irfani, D. R., Saniyah, N. M., Azzahra, T. F., Hikmah, F. A. M., Sahida, D. N., & Suttrisno, S. (2025). Problem-Based Learning Di MI. Jurnal Manajemen Pendidikan, 10(2), 641-657. https://doi.org/10.34125/jmp.v10i2.596

Adnan, M., & Annisa , F. (2025). Analisis Keterampilan Proses Sains Siswa Melalui Kegiatan Praktikum pada Materi Fluida Statistik di SMAN Unggul Pidie Jaya. Relativitas *: Jurnal Riset Inovasi Pembelajaran Fisika* , 8(1), 84-94. https://doi.org/10.29103/relativitas.v8i1.21320

Aisyah , N., Safitri , SL, Zahra, F., & Santoso , DI (2021). Pengembangan E- Modul dengan Model Pembelajaran Berbasis Masalah pada Mata Pelajaran PAI. *Manazhim* , 3(2), 273-284.

Arsyka , ATZ, & Wahyuni , TS (2021). Pengembangan E-Modul Berbasis Multipel Representasi pada Pembelajaran Flipped Classroom Materi Laju Reaksi . *Jurnal Riset Pendidikan Kimia (JRPK),* 11(2), 55-63.

Gustiar, A. W., Saepurokhman, A., & Irianto, A. (2023). Analisis kelayakan isi dan penggunaan bahasa dalam buku teks bahasa indonesia kelas IX SMP Karya Agus Trianto, dkk. sebagai upaya pemilihan bahan ajar bermutu. Literat-Jurnal Pendidikan Bahasa dan Sastra Indonesia, 2(1), 62-70.

Rembet, I., Suriani, N. W., Warouw, Z. W. M., Harahap, F. ., & Mokalu, Y. B. (2026). Pengembangan Lembar Kerja Peserta Didik Elektronik (E-LKPD) IPA Berbasis Web Google Site Menggunakan Model Addie pada Materi Zat Aditif. JagoMIPA: Jurnal Pendidikan Matematika Dan IPA, 6(1), 387–403. https://doi.org/10.53299/jagomipa.v6i1.3209

Susanti, E. D., & Sholihah, U. (2021). Pengembangan e-modul berbasis flip pdf corporate pada materi luas dan volume bola. RANGE: Jurnal Pendidikan Matematika, 3(1), 37-46.

Anggraini, N. T., & Susanti, S. (2025). Pengembangan E-Modul Berbasis Pembelajaran Berdiferensiasi Ditinjau dari Gaya Belajar Siswa pada Elemen Perpajakan Fase F. Jurnal Studi Guru dan Pembelajaran, 8(2), 1188-1200.

Ellysia, A., & Irfan, D. (2021). Pengembangan e-modul dengan flip PDF professional pada mata pelajaran dasar listrik dan elektronika. Vote Teknika, 9, 91-96.

Aulia , RE, Sumiharsono , R., & Triwahyuni , E. (2023). Pengaruh Penggunaan Modul IPA Berbasis Problem Based Learning (PBL) Terhadap Keterampilan Proses Sains dan Kemampuan Berpikir Kritis Siswa . *Jurnal Pendidikan dan Pembelajaran* , 4(2), 1445-1454. https://doi.org/10.62775/edukasia.v4i2.459

Chen, D., Fitriani , R., Maryani , S., Setiya Rini , EF, Putri , WA, & Ramadhanti , A. (2021). Deskripsi Keterampilan Proses Sains Dasar Siswa Kelas VIII pada Materi Cermin Cekung . *Jurnal Pendidikan Sains,* 5(1), 50–55. Https://Doi.Org/10.33369/Pendipa.5.1.50-55

Dianti , P., Sunandar , A., & Setiadi , AE (2023). Analisis Penguasaan Konsep dan Kemampuan Berargumentasi Siswa dengan Model Argument Driven Inquiry Berbasis Sosio-Scientific Issue. Qalam : Jurnal Ilmu Kependidikan , 12(2), 1-14.

Ekici , M., & Erdem , M. (2020). Menyebarkan Keterampilan Proses Sains Melalui Penyelidikan Ilmiah Seluler. Keterampilan Berpikir dan Kreativitas, 36, 100658. https://doi.org/10.1016/j.tsc.2020.100658

Ginting , AAB, Darmaji , D., & Kurniawan , DA (2022). Analisis Pentingnya Keterampilan Proses Sains terhadap Kemampuan Berpikir Kritik di SMA Se-Kecamatan Jurnal Pemayung *Pendidikan MIPA* , 12(1), 91-96.

Hafizah , M. (2024). Pengembangan E- Modul Pembelajaran Berbasis Masalah Berbasis pada Materi Sistem Pencernaan Manusia untuk Meningkatkan Kemampuan Berfikir Kreatif Peserta Didik Kelas *XI* IPA SMA. Jurnal *Inspiratif Pendidikan*

, 12(2), 625-639. https://doi.org/10.24252/ip.v12i2.37516

Hartati , H., Azmin , N., Nasir, M., & Andang , A. (2022). Keterampilan Proses Sains Siswa melalui Model Pembelajaran Problem Based Learning (PBL) pada Materi Biologi . *JIIP- Jurnal Ilmiah Ilmu Pendidikan* , *5* (12), 5795-5799.

Fernandes, M., & Syarifuddin, H. (2020). Pengembangan Perangkat Pembelajaran Pecahan Berbasis Model Penemuan Terbimbing untuk Kelas IV SD. ELSE (Elementary School Education Journal): Jurnal Pendidikan Dan Pembelajaran Sekolah Dasar, 4(1), 20-35. https://doi.org/10.30651/else.v4i1.4011

Hasibuan , YR, & Sugiharti , G. (2025). Pengembangan e-modul berbasis *Isu-isu Sosio Ilmiah* (SSI) pada materi laju Reaksi untuk meningkatkan Kemampuan berpikir kritis . *Panthera : Jurnal Ilmiah Pendidikan Sains dan Terapan* , *5* (3), 833–845. https://doi.org/10.54371/jiip.v5i12.1190

Irawan , RS, Haris , M., & Hidayanti , E. (2024). Pengaruh Pembelajaran Berbasis Proyek Berbantuan Media Komik Terhadap Keterampilan Proses Sains Kimia Materi Laju Reaksi pada Siswa Kelas XI MIPA SMAN 1 Lembar . *Praktek Pendidikan Kimia* , 7(2), 388-394. https://doi.org/10.29303/cep.v7i2.6625

Isma, EF, & Novita, D. (2021). Implementasi LKPD Inkuiri Terbimbing Online untuk Melatihkan Kemampuan Berpikir Kritis Materi Faktor Laju Reaksi . *Praktek Pendidikan Kimia,* 4(1), 10-18.

Puspitasari, E., Abdullah, A., & Wati, M. (2025). Validasi: lkpd terintegrasi model problem based learning untuk melatih keterampilan berpikir kritis materi asam basa. Jurnal Pendidikan MIPA, 15(1), 129-137.

Islahiyah , I., Pujiastuti , H., & Mutaqin , A. (2021). Pengembangan E- Modul dengan Model Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis Siswa . AKSIOMA: *Jurnal Program Studi Pendidikan Matematika* , 10(4), 2107.

Kusuma , E., Handayani , A., & Rakhmawati , D. (2024). Pentingnya Pengembangan Kemampuan Berpikir Kritis pada Siswa Sekolah Dasar : Sebuah Tinjauan Literatur . *Jurnal Wawasan Pendidikan* , 4(2), 369-379.

Mardhiyah , RH, Aldriani , SNF, Chitta , F., & Zulfikar , MR (2021). Pentingnya Kemampuan Belajar di Abad 21 Sebagai Tuntutan dalam Pengembangan Sumber Daya Manusia . *Lectura : Jurnal Pendidikan* , 12(1), 29-40. https://doi.org/10.31849/lectura.v12i1.5813

Nazar , AM, Sulisawati , DN, & Hidayatin , N. (2025). Kemampuan berpikir Kritis Matematis Siswa SMP Setelah Penerapan Video Edukasi dalam Proses Pembelajaran . Pristika : *Jurnal Pendidikan dan Riset Matematika* , 7(2), 321-338. https://doi.org/10.33503/pristika.v7i2.1095

Pantiwati , Y., Permana , FH, Aminudin , & Sari, TNI (2024). *Prototipe e- modul model pembelajaran LI-PRO-GP*. Malang : Pers UMM.

Pramana , MWA, Jampel , IN, & Pudjawan , K. (2020). Meningkatkan Hasil Belajar Biologi Melalui E-Modul Pembelajaran Berbasis Masalah. *Jurnal Edutech Undiksha* , 8(2), 17-32. https://doi.org/10.23887/jeu.v8i2.28921

Purnamasari , J., Wardhani , S., & Nawawi , S. (2021). Analisis Soal Keterampilan Proses Sains (KPS) pada Materi Biologi di SMA Kota Palembang. *Jurnal Pendidikan* , 7(1), 9-17. https://doi.org/10.19109/bioilmi.v7i1.9484

Purwanti , E., & Heldalia , H. (2020). Korelasi Keterampilan Proses Sains dengan Kemampuan Berpikir Kritis Siswa pada Materi Pemantulan pada Cermin Data . *Jurnal Evaluasi dalam Pendidikan (JEE),* 1(4), 143-148. https://doi.org/10.37251/jee.v1i4.146

Putra, T., Evi Fatimah, A., & Kesumawati , D. (2021). Pengaruh Model Pembelajaran Problem Based Learning (PBL) Terhadap Kemampuan Berpikir Kritis pada Materi Sistem Pencernaan di Kelas XI Sma Negri 1 Stabat . *Jurnal Penelitian , Pemikiran , dan Pengabdian* , 8(2).

Qadariah , N., Kurniati , T., Suri, NA, Lufri , L., Andromeda, A., & Mufit , F. (2025). Mengungkap Dampak PBL pada Tim Komunikasi dan Kerja di Kalangan Mahasiswa Biologi. *JPBI (Jurnal) Pendidikan Biologi Indonesia),* 11(1), 262–273. https://doi.org/10.22219/jpbi.v11i1.38289

Rizaldi , R., & Syahwin , S. (2023). Praktikalitas e- Modul Praktikum Fisika SMA Berbasis Model Pembelajaran Problem Based Learning (PBL) terhadap Keterampilan Proses Sains Siswa SMA. Jurnal Pendidikan MIPA, 13(4), 1030-1037. https://doi.org/10.37630/jpm.v13i4.1275

Salmiah . (2020). Penerapan Pendekatan Keterampilan Proses Sains Terhadap Peningkatan Hasil Belajar Sains Siswa Kelas VIII Mts Negeri 1 Donggala . *Jurnal Kreatif Online,* 8(1), 159–168.

Aulina, S. (2026). Validitas Perangkat Pembelajaran Articulate Storyline Terintegrasi Etnomatematika untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis. *Jurnal Media Akademik* (JMA), 4(7). https://doi.org/10.62281/d61xpw18

Sartika , I., Dafrita , IE, & Nawawi , N. (2024). Pengembangan E- Modul Berbasis Problem Based Learning (PBL) Terhadap Kemampuan Berpikir Kritis Siswa Pada Materi Sistem Pencernaan Manusia Kelas XI SMAN 1 Samalantan . *BIODIK,* 10(3), 311-320. https://doi.org/10.22437/biodik.v10i3.30448

Siddiq , R. (2020). Pengembangan E- modul Interaktif Berbasis Android pada Mata Kuliah Strategi Belajar

Mengajar . *Jurnal Pendidikan Sejarah* , 9(1),1-14. https://doi.org/10.21009/JPS.091.01

Sihombing , N., & Suyanti , RD (2022). Pengaruh Model Pembelajaran Siklus Berorientasi Pembelajaran Kolaboratif Berbantuan E- Modul Laju Reaksi terhadap Kemampuan Pemecahan Masalah Siswa . *Jurnal Indonesia Sosial Sains , 3(3), 469082.* https://doi.org/10.36418/jiss.v3i3.560

Biggs, J., & Tang, C. (2011). Teaching for Quality Learning at University (4th ed.). Open University Press.

Sudjana , N. (2006). Penilaian Hasil Proses Belajar Mengajar Bandung: Remaja Rosdakarya .

Waruwu, M. (2024). Metode penelitian dan pengembangan (R&D): konsep, jenis, tahapan dan kelebihan. Jurnal Ilmiah Profesi Pendidikan, 9(2), 1220-1230.

Utami, N. C. M. (2023). Analisis kebutuhan pengembangan bahan ajar menulis teks deskripsi di sekolah dasar. Jurnal Elementaria Edukasia, 6(2), 360-373.

Surya, PM, & Surya, PDM (2022). Pengembangan E-Modul Pembelajaran IPA Berbasis Inkuiri Terbimbing untuk Menekan Keterampilan Proses Sains Siswa . Wahana Matematika dan Sains : *Jurnal Matematika , Sains , dan Pembelajarannya* , 15(3), 86–97. https://doi.org/10.23887/wms.v15i3.38239

Tazkiyah, Y., & Suryapermana , N. (2020). Pengaruh Model Pembelajaran Berbasis Masalah dan Kemampuan Berpikir Kritis Terhadap Hasil Belajar Siswa pada Mata Pelajaran PAI (Studi Eksperimen di SMK Negeri 1 Puloampel Kabupaten Serang). *Jurnal Pendidikan Agama Islam,* 7(2). https://www.maxmanroe.com/vid/umum/standar-nasional

Utari , WM, Gunada , IW, Makhrus , M., & Kosim , K. (2023). Pengembangan E- Modul Model Pembelajaran Fisika Pembelajaran Berbasis Masalah Berbasis Flipbook untuk Menekan Kemampuan Berpikir Kreatif Peserta Didik . *Jurnal Ilmiah Profesional Pendidikan* , 8(4), 2724-2734. https://doi.org/10.29303/jipp.v8i4.1822

Wahyuni , S., & Hambali , H. (2024). Keterampilan Proses Sains untuk Menekan Hasil Belajar IPA Siswa Sekolah Dasar . *Jurnal Ilmu Pendidikan Dasar Indonesia,* 3(2), 85-95. https://doi.org/10.51574/judikdas.v3i2.1229

Warahmah , M., Rahmawati , R., & Siahaan , J. (2021). Pengaruh Model Pembelajaran Berbasis Masalah Terhadap Kemampuan Berpikir Kritis Siswa Kelas XI MIA SMA Negeri 1 Kediri Tahun Pelajaran 2019/2020 pada Materi Larutan Penyangga . *Praktek Pendidikan Kimia* , 4(1), 73. https://doi.org/10.29303/cep.v4i1.2200

Zainuri , BNS, Gunawan , G., & Kosim , K. (2025). Pengenalan E- Modul Berbasis PBL Terintegrasi Kearifan Lokal untuk Menekan Literasi dan Keterampilan Proses Siswa di SMPN 15 Mataram . *Jurnal Pendidikan dan Pengabdian Kepada Masyarakat* Indonesia , 5(1), 48-53. https://journal.publication-center.com/index.php/ijecs/article/view/1828