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Developing a Problem-Based Learning E-Module to Enhance Students' Understanding of Elements, Compounds and Mixtures in Chemistry

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Abstract. This study evaluates the viability of a problem-based learning (PBL) e-module on elements, compounds, and mixtures through validation by experts and feedback from both teachers and students. This study adopted a research and development (R&D) methodology guided by the ADDIE framework. The participants consisted of teachers and students from SMPN 10 Pontianak. The data were gathered using an indirect communication method, specifically through feasibility assessment sheets and questionnaires filled out by both teachers and students. The results indicated that the e-module was considered highly suitable for use. The validity coefficient were 1.00 from graphic design experts (categorized as very good), 0.83 from linguists (very good), and 1.00 from subject matter experts (very good). The average coefficient from experts validation was 0.94, which fall into the very good category. In addition, teacher and student responses also indicated very good results: for the media aspect, each response rates were 92% and 85%; for the content aspect, 85% and 83%; and for usefulness, 86% and 85%. These results suggest that the PBL-based teaching e-module is suitable and ready to be used in learning activities.
Keywords: E-module teaching, problem-based learning, elements, compounds and mixtures

Introduction

Learning is a fundamental process for acquiring knowledge and developing students' abilities, transforming them from not knowing to knowing. Therefore, the learning process is expected to be of high quality in supporting students to construct their own understanding (Hasan et al., 2021). This philosophy is in line with Ki Hajar Dewantara's educational principles and the implementation of the current merdeka curriculum, which is learner-centered (Wahidah et al., 2025). Quality learning requires deliberate efforts to create a pleasant and conducive learning environment by providing direct experiences. According to Wismath et al. (2015) When students are actively engaged in the learning process, their critical thinking and problem-solving abilities tend to improve. Such experiences can be fostered through collaboration and social interaction, supported by the teacher's ability to guide students in actively participating in the learning process.

Thus, active learning is expected to enhance students' potential and their awareness of the surrounding environment. This can be achieved through the use of engaging learning

media that support an effective learning process (Yuningsih et al., 2023). Therefore, teachers are required to be more creative in developing innovative learning media by designing instruction that promotes collaboration, creativity, and problem-solving, as well as by creating a learning environment that is responsive to students' needs (John, 2024). However, field observations indicate that many teachers still do not utilize a variety of learning media to effectively capture students' attention during the learning process (Yulis, 2024).

Based on observations conducted at SMPN 10 Pontianak, several issues were identified in science learning, particularly in the topic of elements, compounds, and mixtures. Students appeared less active, unfocused, and less serious in completing tasks. In addition, the learning media used were suboptimal. For example, the student worksheets (LKPD) were still limited, lacking a clear instructional model syntax, and the questions provided did not stimulate students to think critically. Furthermore, the practical activities in the LKPD were not contextualized with everyday life, thus failing to train students in environmental awareness. Therefore, it is necessary to develop appropriate learning media and approaches to enhance students' critical thinking skills (CTS) and motivation to learn more effectively.

The problem-based learning (PBL) approach is recognized as an effective pedagogical method for enhancing students' CTS, as it facilitates collaborative learning, promotes self-awareness, and engages learners in solving authentic, real-world problems (Murphy et al., 2025). According to previous research by Anwar et al. (2023), PBL had a significant effect of 1.87 in enhancing students' CTS. Furthermore, a study by Kharismanda et al. (2024) found that the implementation of PBL significantly improved student learning outcomes in the topic of elements, compounds, and mixtures-from 40.63% in cycle 1 to 78.13% in cycle 2. In addition, a literature review by Hamid, (2022) reported that the application of the PBL model improved students' CTS by 40% compared to traditional learning methods. Research by Knopfel et al. (2024), also indicated that the application of PBL significantly enhanced students' problem-solving skills, even in the short term, as students were guided to identify problems, engage in collaborative discussions, and formulate solutions. These findings suggest that the PBL model has a significant impact on improving students' CTS and learning motivation.

In addition to the implementation of an effective learning model, the use of appropriate learning media is also a crucial factor in supporting learning achievement. PBL delivered through e-modules can enhance students' ability to learn independently and improve their understanding of complex concepts in the learning content (Margalita et al., 2025). This is supported by the findings of Yulando et al. (2019), which showed that electronic modules equipped with features such as quizzes not only increased students' motivation and participation in learning, but also fostered a more active, enjoyable, and flexible learning environment. Furthermore, research by Jayanti & Pertiwi (2023) demonstrated that the use of PBL-based teaching e-modules had a significant impact on students' CTS. Similarly, Rizaldi et al. (2022) reported that PBL-based teaching e-modules integrated with practicum activities achieved an effectiveness score of 75.41 in improving students' process skills. In addition, Sari et al. (2025) found that the use of PBL-based modules significantly enhanced students' CTS, with a t-test result of 0.000 and an achievement rate of 86.67%, indicating substantial development. Thus, previous research suggests that using PBL-based teaching e-modules is an effective way to improve students' critical thinking abilities.

The development of PBL-based e-modules on the topic of elements, compounds, and mixtures is proposed as a solution to the issues identified at SMPN 10 Pontianak. This initiative is intended to foster greater interest and motivation among students in learning science. Furthermore, the developed e-modules are anticipated to enhance the quality of

science instruction and function as a pedagogical reference for educators in creating innovative instructional materials that align with the objectives of the merdeka curriculum.

Methods

This research follows a research and development (R&D) approach to carefully design, create, and evaluate the product's feasibility prior to its practical application (Sugiyono, 2022). The model used is the ADDIE model-analysis, design, development, implementation, and evaluation. However, this study is limited to the first three stages: analysis, design, and development (Branch, 2009). The ADDIE model is designed to suit the needs and characteristics of learning, emphasizing simplicity, structure, systematic flow, and interconnectivity, in order to minimize errors or deficiencies in the developed product (Nurhikmah et al., 2023). The steps of the ADDIE model can be seen in Figure 1.

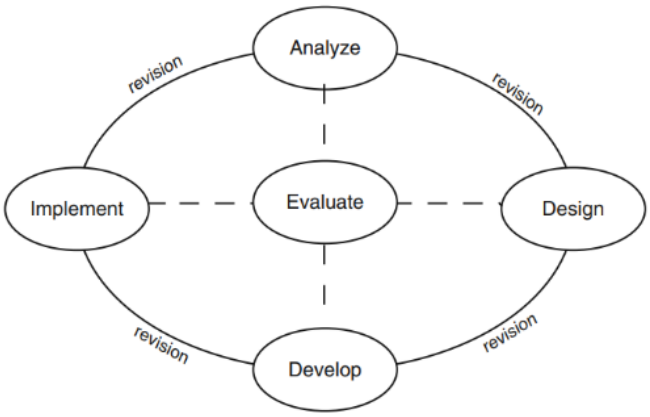

Figure 1. The Steps of the ADDIE Model (Branch, 2009)

The first step in the ADDIE model is the analysis stage, which involves activities such as problem analysis, needs analysis, and curriculum analysis related to learning outcomes integrated into the teaching e-modules. These activities involve both teachers and students in reviewing the existing teaching content, learning models, and subject content, as well as analyzing the learning objectives (CP) and learning achievements (TP) outlined in the current merdeka curriculum. This stage serves as an initial step in designing the e-module product as an effort to enhance the effectiveness of an engaging and efficient learning process (Salsabila et al., 2024).

The second step, namely the design stage, begins with preparing the e-module content framework based on the merdeka curriculum by formulating the CP into TP. A storyboard is then developed to outline the flow of material presentation, PBL activities, and the e-module's visual design, which includes layout, illustrations, and color selection. At this stage, instruments for data collection are also prepared. The design stage results in an initial prototype of the e-module that is ready to be validated by experts and subsequently tested.

The third step, the development stage, was conducted by validating the e-module through an assessment process involving experts in language, graphics, and content. Validation was carried out by two validators for each aspect, after which revisions were made and responses from teachers and students were tested using a response questionnaire. The respondents consisted of three science teachers from SMPN 10 Pontianak and 31 students from class IXG who had previously studied the topic in class VIII. The data collection techniques included validation sheets as well as teacher and student response questionnaires, which utilized a four-point Likert scale: 4 (strongly

agree), 3 (agree), 2 (disagree), and 1 (strongly disagree), to assess the responses toward the e-module on elements, compounds, and mixtures.

The data collected from expert validation sheets, as well as teacher and student responses, were analyzed using a combination of quantitative and qualitative methods. The quantitative data analysis, using Gregory's formula for expert validation, is presented in Table 1.

Table 1. Gregory matrix

		Appraiser 1	
		Less relevant (Score 1-2)	Very relevant (Scores 3-4)
Appraiser 2	Less relevant (Score 1-2)	A	B
	Very relevant (Scores 3-4)	C	D

(Source: Lestari et al., 2024).

Based on Table 1, to calculate the results of the expert assessment, the scoring system uses a range of 1-2 for the "less relevant" category and 3-4 for the "very relevant" category. This system aims to facilitate decision-making. The formula used is based on Gregory's formula.

$$\text{Content Feasibility} = \frac{\text{D}}{\text{A} + \text{B} + \text{C} + \text{D}} \qquad (1)$$

Notes:

A : Total number of items with irrelevant ratings from both raters
B : Total number of items with irrelevant ratings from rater 1
C : Total number of items with irrelevant ratings from rater 2
D : Total number of items with relevant ratings from both raters

The obtained scores are then interpreted using a qualitative table, which can be seen in Table 2.

Table 2. Criteria for validation results eligibility

Coefficient	Criteria
0.80 – 1.00	Very Good
0.60 – 0.79	Feasible
0.40 – 0.59	Satisfactory
0.20 – 0.39	Not Feasible
0.00 – 0.19	Very Unfeasible

(Source: Istiqomah et al., 2022).

Based on Table 2, the feasibility assessment used to evaluate the product includes four criteria for determining its feasibility, as rated by experts, with a coefficient range of 0.00 to 1.00, spanning from the "very unfeasible" to "very good" categories. To analyze the data quantitatively for both the teacher's and students' responses, the formula provided by Riduwan (2018) is applied. The questionnaire used to measure the responses consists of the following categories: STS (strongly disagree), TS (disagree), S (agree), and SS (strongly agree). These categories are applied to positive statements, with scores ranging from 1 to 4. For negative statements, the scores range from 4 to 1, allowing for a

systematic measurement of these responses. The following is the formula according to Riduwan (2018).

$$P = \frac{\Sigma X}{\Sigma Xi} \text{ x } 100\% \qquad (1)$$

Description:

P : Percentage of score acquisition

ΣX : Total score for each statement

ΣXi : Number of highest scores

To calculate the average percentage of student and teacher responses to the learning module as a whole, the following formula is used.

$$P \text{ total} = \frac{\Sigma P}{n} \qquad (2)$$

Description:

P total : Average percentage of responses

ΣP : The sum of the average percentage scores for each aspect

n : Number of aspects assessed

The results of the teacher and learner response data are then interpreted based on the assessment criteria according to Riduwan, (2018) as shown in Table 3.

Table 3. Teacher and learner response criteria

Score learner response	Criteria
0 - 20	Very Poor
21 - 40	Poor
41 - 60	Fair
61 - 80	Good
81 - 100	Very Good

(Source: Riduwan, 2018).

Based on Table 3, the assessment of the developed e-learning module encompasses five feasibility criteria within a percentage range of 0–100%, categorized from very poor to very good. The obtained data will then be compared with the response criteria table to determine teachers' and students' responses to the developed e-module. In addition, qualitative data in the form of suggestions from validators will serve as the basis for revising the product prior to conducting a limited trial at SMPN 10 Pontianak.

Results and Discussion

This study focuses on the development of a PBL-based e-module on elements, compounds, and mixtures for eighth-grade students. The development process followed the ADDIE model, limited to the development stage, which included validation to assess the responses of both teachers and students. The results obtained during the development of the e-module are presented as follows:

The first stage, namely the analysis stage, was carried out to obtain the necessary data for designing PBL-based e-modules on elements, compounds, and mixtures. This stage involved problem analysis, needs analysis, and curriculum analysis. The purpose of the analysis was to develop effective and relevant learning content. An analysis of the

existing learning process was carried out to identify prevailing challenges; a needs analysis was undertaken to assess the requirements of both teachers and students, ensuring that the developed e-modules address those needs; and a curriculum analysis was conducted to ensure alignment with current educational standards and the applicable curriculum. The results of the analysis stage are presented in Table 4.

Table 4. Results of the needs analysis

No	Analysis stage	Results
1	Problem analysis	The use of learning resources at SMPN 10 Pontianak is still limited, relying on LKPD that do not incorporate a specific learning model syntax. Students tend to be less active, unfocused, and not fully engaged in completing tasks.
2	Needs analysis	It is necessary to develop more varied teaching content that incorporate active learning methods to enhance students' interest and understanding, as well as to foster the development of their CTS.
3	Curriculum analysis	The current curriculum is the independent curriculum, which focuses on relevant learning outcomes and the application of practical activities to connect the material with everyday life.

Based on Table 4, it is evident that there are limitations in the teaching content used, and a lack of student motivation is one of the key issues at SMPN 10 Pontianak. As a result, students tend to be less motivated and less critical in completing tasks effectively. To address these issues, it is necessary to innovate in the development of learning media and to select appropriate learning models that encourage students to remain active and critical throughout the learning process (Aisyah et al., 2021). One effective solution is the use of electronic-based e-modules, which can be accessed at any time and updated in accordance with curriculum requirements. With attractive designs and relevant content, these e-modules can enhance students' motivation and CTS, thereby optimizing the learning process (Yulis, 2024).

Based on the aforementioned problems, a PBL-based teaching e-module was developed in the form of a flipbook. This problem-focused electronic learning media is designed to encourage students to remain active and critical in solving real-life problems (Muthia & Anggereini, 2023). It is therefore expected that students will become more engaged and better able to develop their CTS.

The second stage, the design stage, involved preparing the learning media using microsoft word 2021, canva pro, and the heyzine PDF to flipbook website. The e-module was structured to follow the standard components commonly found in teaching modules, including a cover, module identity, preface, table of contents, learning guidelines, and general information such as module details, initial competencies, the Pancasila student profile, required infrastructure, and the learning model. The main content consists of learning objectives, key concepts, guiding questions, assessments, learning tasks, and opportunities for reflection. Additionally, the module contains attachments such as LKPD, enrichment and remedial content, reading content, glossary, bibliography, and assessment instruments.

The preparation of this e-module is based on the guidelines by Ulfa et al. (2024), which outline teaching module components aligned with the merdeka curriculum. The content compiled in this e-module follows the PBL syntax proposed by Pertiwi et al. (2023), This includes several stages: introducing the problem, organizing students for learning, supporting group investigations, guiding the creation and presentation of their work, and

reviewing as well as assessing the problem-solving process. Accordingly, the presentation of content on elements, compounds, and mixtures is adapted to this PBL syntax, where students are directed to solve problems related to the learning content. The problems presented are real-life issues encountered in daily life. Subsequently, the activities carried out by students consist of problem-solving tasks and practicum activities.

The third stage, namely the development stage, involved producing the teaching e-modules and presenting them in the form of a flipbook. The modules were then validated by experts to determine the feasibility of their content prior to use. The recapitulation of the assessment results by graphic experts is shown in Table 5.

Table 5. Recapitulation of graphic expert assessment results

No	Before revision	After revision
1	The title on the cover does not accurately reflect the content.	The title on the cover was improved by adding a comma (,) after the word element, as shown in figure 2.
2	The color selection on the cover requires more consideration.	The color scheme was adjusted by selecting three dominant colors: green, white, and black, as shown in figure 2.
3	The cover image and the author's name are not visually appealing.	The cover image was revised to feature a picture of the periodic table of elements, and the author's name was added to the background, as shown in figure 2.
4	The image size in the questions of the LKPD is too small.	The image size in the LKPD questions was standardized, as shown in figure 3.
5	The e-module template is not visually engaging, and the page numbers are poorly aligned with jagged accents.	The template was enhanced to be more colorful, and the page numbers were changed to a round format, as shown in figure 4.

Based on Table 5, it can be seen that improvements to the title, images, and colors on the module display, made in response to the comments and suggestions from the graphic expert, details of improvements a is down Figure 2.

(a) **(b)**

Figure 2. Improvements in graphic aspects, (a) before revision & (b) after revision

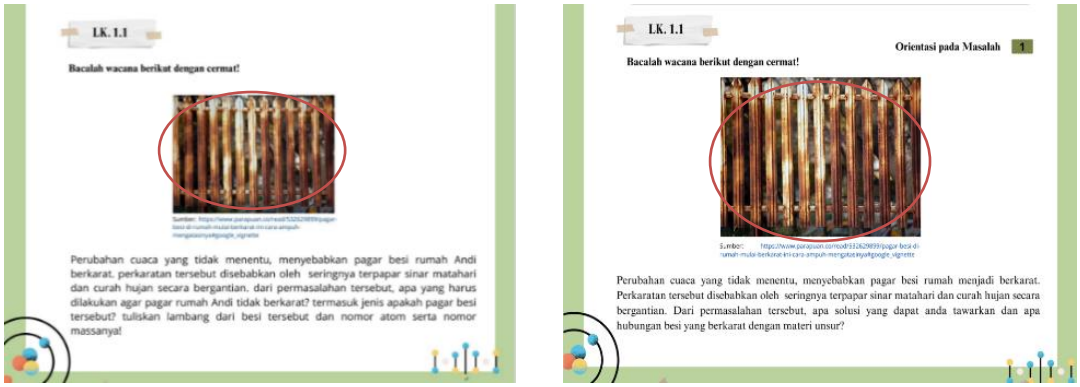

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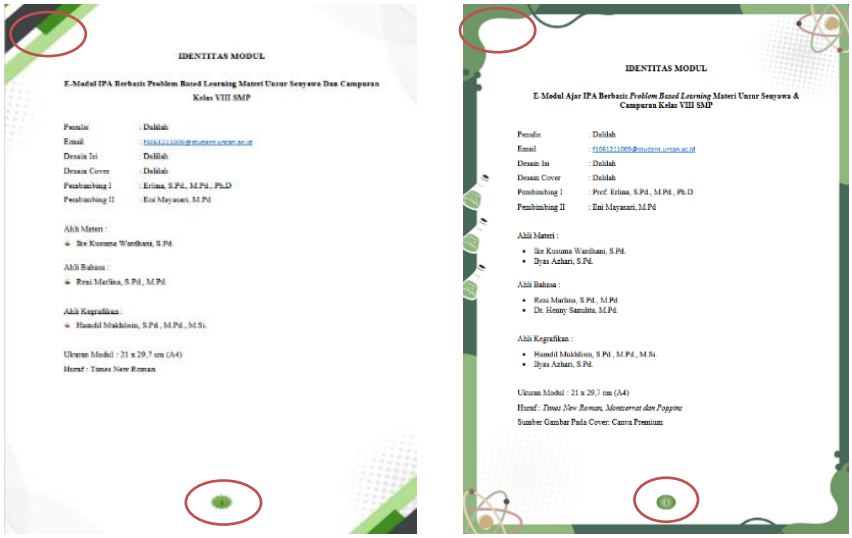
Figure 3. Improvements in graphic aspects, (a) before revision & (b) after revision



(a) **(b)**

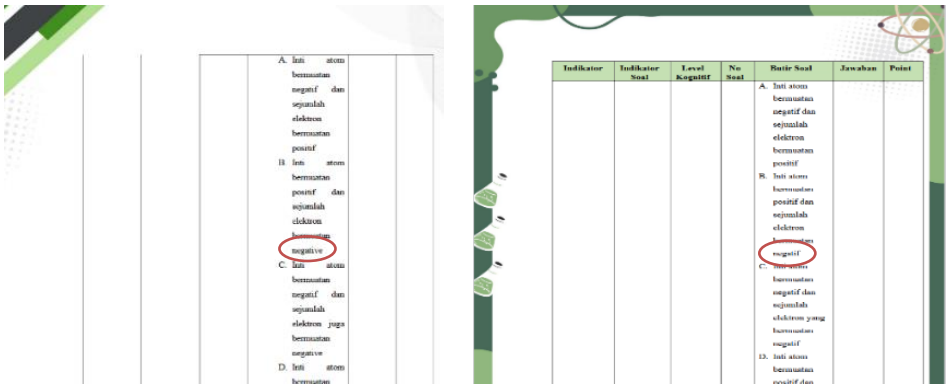
Figure 4. Improvements in graphic aspects, (a) before revision & (b) after revision

The recapitulation of the assessment results by language experts is presented in Table 6

Table 6. Recapitulation of assessment results by language experts

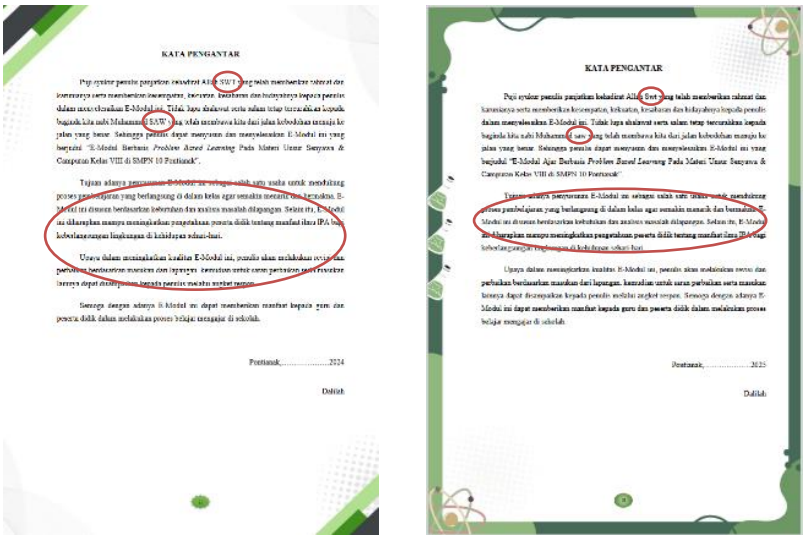
No	Before revision	After revision
1	There is a typo in the word 'negative' in one of the questions in the e-module.	Corrected to the word 'negative,' as shown in figure 5.
2	In the preface, the use of the abbreviations 'SWT' and 'SAW' is inappropriate, and the third and fourth paragraphs should be combined.	The abbreviation 'SWT' was changed to 'Swt,' and 'SAW' to 'saw'; the third and fourth paragraphs were also combined, as shown in figure 6.
3	The use of symbols in the learning activities is inaccurate, and the word 'invites' is also used incorrectly.	Symbols were replaced with numbers, and the incorrect use of the word 'invites' was corrected in the learning activities, as shown in figure 7.

Based on Table 6, detail of improvements to the vocabulary section of the e-module content, as suggested by linguists, can be seen in Figure 5.



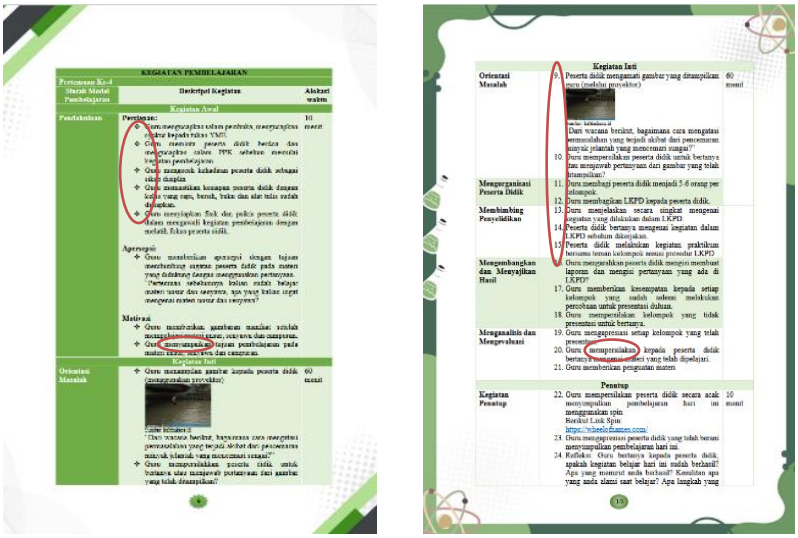
(a) **(b)**

Figure 5. Improvement of language aspects: (a) before revision & (b) after revision



(a) **(b)**

Figure 6. Improvement of language aspects: (a) before revision & (b) after revision



(a) **(b)**

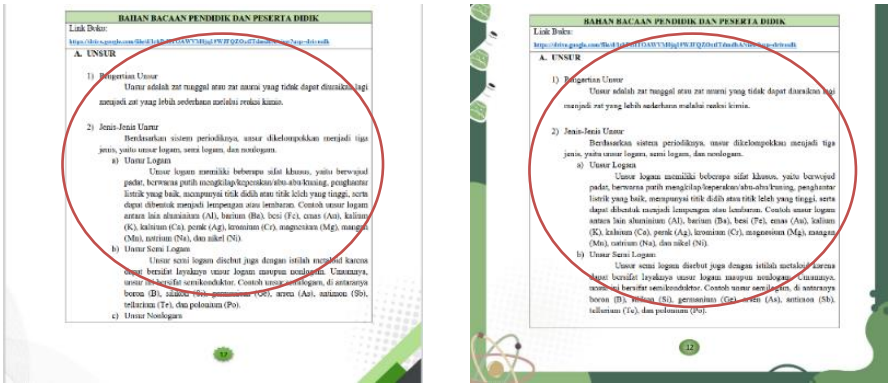
Figure 7. Improvement of language aspects: (a) before revision & (b) after revision

The recapitulation of the topic experts' assessment results can be seen in Table 7.

Table 7. Recapitulation of topic experts' assessment results

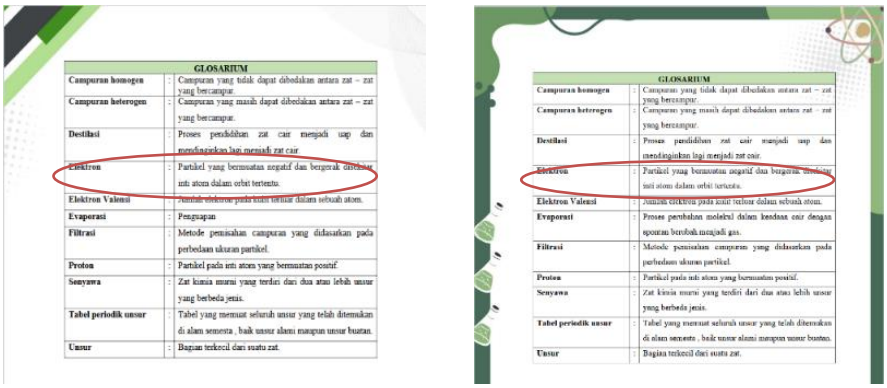
No	Before revision	After revision
1	The reading topic provided in the e-module is not comprehensive.	Additional reading content on the mixture separation method was added, as shown in figure 8.
2	The reading topic in the e-module lacks completeness."	The term evaporation was accompanied by a more complete explanation, namely: 'Evaporation is the process of changing molecules in a liquid state spontaneously into gas,' as shown in figure 9

Based on Table 7, detail of improvements can be seen in the completed content of the e-module, as informed by the comments and suggestions of the content expert, which are illustrated in Figure 8



(a) **(b)**

Figure 8. Improvements in topic aspects: (a) before revision & (b) after revision



(a) **(b)**

Figure 9. Improvements in topic aspects: (a) before revision & (b) after revision

The results of the graphical, language, and content validations are calculated using the Gregory formula, with two validators for each assessor, as shown in Table 8.

Table 8. Results of expert validation for graphics, language, and topic aspects

Aspects	Coefficient	Category
Graphics	1.00	Very Feasible
Language	0.83	Very Decent
Topic	1.00	Very Feasible

Based on the calculation of the assessment of the graphical aspect, namely the evaluation of the teaching e-modules by two experts, a coefficient value of 1.00 was obtained, indicating a 'very valid' or 'very feasible' category. This demonstrates that, graphically, the appearance of the e-module, including the layout and colors used on both the cover and content, is cohesive and harmonious. Therefore, with an attractive e-module design, it is expected to enhance student motivation in learning about elements, compounds, and mixtures, while providing a meaningful learning experience that encourages students to become more active in the learning process (Kautsari et al., 2023).

Based on the results of the language aspect assessment, namely the evaluation of the teaching e-modules by two experts, a coefficient value of 0.83 was obtained, indicating a 'very valid' or 'very feasible' category. This demonstrates that, in terms of language, the use of sentences in the e-module adheres to the PUEBI Indonesian guidelines, avoiding ambiguous interpretations (Wahyuni et al., 2025). Additionally, the sentence structure and language used are considered effective in helping students understand the content on elements, compounds, and mixtures. Therefore, the use of proper and correct Indonesian in teaching content is expected to facilitate students' understanding during the learning process (Istiqomah et al., 2022).

Based on the results of the content aspect assessment, namely the e-module evaluation by two experts, a coefficient value of 1.00 was obtained, indicating a 'very valid' or 'very feasible' category. This demonstrates that the content presented aligns with the learning outcomes outlined in the merdeka curriculum. Additionally, the presentation of the content in the e-module follows the PBL steps, and the problems presented in the content are relevant to everyday life and appropriate for the students' level of knowledge. Therefore, it is expected that students will become more active and improve their CTS in learning about elements, compounds, and mixtures (Istiqomah et al., 2022).

Thus, based on the assessment of the graphical, language, and content aspects, the overall average validation score of the teaching e-modules is 0.94, placing it in the 'very good' category. Therefore, it can be concluded that the developed teaching e-module is

suitable for testing. These results are consistent with research conducted by Wibisana et al. (2022).

Teacher's Responses

After being declared feasible by the experts (validators), a teacher response test was conducted on the developed teaching e-module. The test involved three teachers from SMPN 10 Pontianak as respondents. The aspects included in the teacher response questionnaire were the appearance of the e-module, the alignment of the content with the learning outcomes, systematics, and its usefulness for students. The results of each teacher's response can be seen in Figure 10.

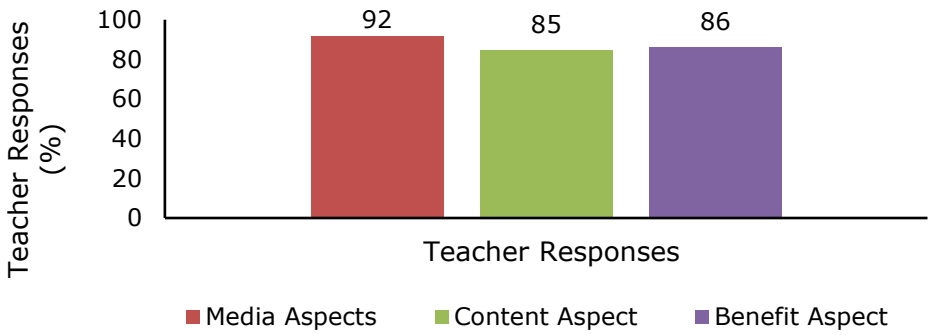


Figure 10. Graph of the teacher response results

Based on Figure 10, the graph of the results of teacher responses to the PBL-based teaching e-modules on element, compound, and mixture content shows that, in the media aspect, a percentage of 92% was achieved, placing it in the 'very good' category. This indicates that the teaching e-module has an attractive visual appearance, a systematic layout, and interactivity that supports the learning process. The content aspect received a percentage of 85%, also in the 'very good' category, reflecting that the content of the content in the e-module is systematically organized, aligns with the curriculum, and effectively encourages students to develop CTS through the PBL approach. Meanwhile, the usefulness aspect received a score of 86%, showing that the e-module has a positive impact on learning effectiveness—especially in improving students' conceptual understanding and encouraging active participation in the learning process. In conclusion, the developed e-module achieved a successful design, as indicated by an overall average score of 88%, demonstrating its effectiveness as a supplementary teaching material. Its engaging, well-structured, and problem-based design is expected to support students in enhancing their CTS and maintaining focus during the learning process (Ismail et al., 2024).

Learner's Response

After the teacher response test was conducted, the next step was to carry out a student response test with a total of 31 respondents from SMPN 10 Pontianak. The aspects included in the student response questionnaire were the appearance of the e-module, ease of understanding the content, and its benefits for students. The overall results of the student responses can be seen in Figure 11.

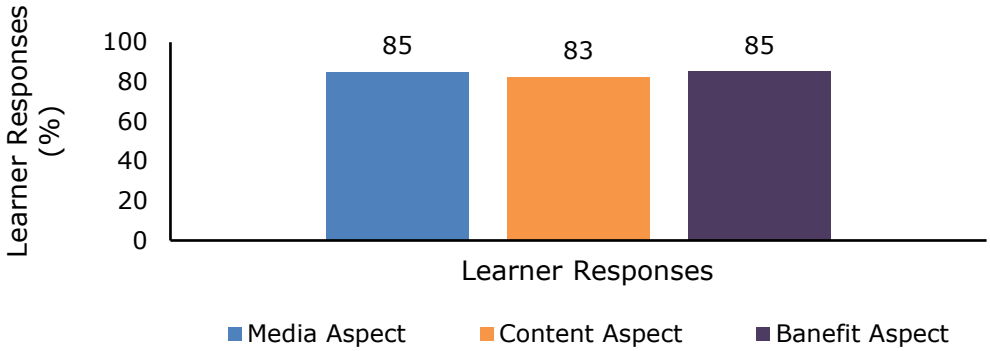


Figure 11. Graph of the learner response results

Based on Figure 11, the graph of the students' response results shows significant variation in their responses to the developed teaching e-modules. In terms of media aspects, the e-module received a score of 85%, placing it in the 'very good' category. This suggests that its visual design and presentation were found to be highly engaging, interactive, and effective in helping students easily access and understand the given problems. Furthermore, the content aspect scored 83%, placing it in the 'very good' category. This indicates that the e-module's content was well-structured, aligned with the PBL approach, and effective in promoting critical thinking through contextual problem-solving in science education. The benefit aspect achieved a score of 85%, which is categorized as 'very good'. This indicates that the utilization of the e-module effectively enhanced students' conceptual comprehension and fostered their independent problem-solving abilities. The overall average percentage for each aspect was 84%, which indicates that this PBL-based teaching e-module received a positive response and is effective and feasible to use as supplementary media in science learning. It aims to increase active involvement and conceptual understanding among students through real-world problems (Rahmawati et al., 2022).

Conclusion

This study concludes that the PBL e-module on elements, compounds, and mixtures is both valid and feasible for classroom implementation. Validation from graphic design, linguistic, and subject matter experts consistently placed the e-module in the "very good" category, with an average coefficient of 0.94, indicating strong reliability and content appropriateness. In addition, teacher and student responses confirmed its effectiveness, highlighting positive evaluations in media design, content accuracy, and practical usefulness, with percentages consistently above 80%. These results collectively demonstrate that the developed e-module is not only ready for use in classroom practice but also has the potential to improve the quality of science learning by fostering student engagement, supporting inquiry, and promoting meaningful learning through the PBL approach. Future implementation and wider trials are recommended to explore its long-term impact on students' conceptual understanding and problem-solving skills.

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The authors respectfully express their deepest gratitude to all validators for their constructive feedback and corrections during the validation of the developed media. The authors also extend their sincere thanks and appreciation to the principal and teachers of

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References

Aisyah, R.S.S., Solfarina, S., & Yuliantika, U. (2021). Pengembangan E-Modul Berbasis Pemecahan Masalah pada Materi Larutan Elektrolit dan Non-Elektrolit (ELNOEL) [Development of Problem-Solving-Based E-Modules on Electrolyte and Non-Electrolyte Solutions (ELNOEL)]. *Hydrogen: Jurnal Kependidikan Kimia*, 9(1), 19-28. https://doi.org/10.33394/hjkk.v9i1.3715

Anwar, I., Rohmani, L.A., & Putra, A.A.I.A. (2023). Peningkatan Berpikir Kritis Siswa SMP Dalam Pembelajaran IPA Melalui Model Pembelajaran Problem Based Learning [Improving Critical Thinking Among Junior High School Students in Science Learning Through the Problem-Based Learning Model]. *Jurnal Jendela Pendidikan*, 3(1), 145–151. https://doi.org/10.57008/jjp.v3i01.430

Branch, R.M. (2009). *Instructional Design: The ADDIE Approach*. New York: Springer. https://doi.org/10.4324/9780429425240-105

Hamid, N., Dasna, I.W., & Habiddin, H. (2022). Kajian Literatur: Implementasi Problem Based Learning (PBL) Dalam Pembelajaran Kimia [Literature Review: Implementation of Problem-Based Learning (PBL) in Chemistry Education]. *Hydrogen: Jurnal Kependidikan Kimia*, 10(2), 209–223. http://ojs.undikma.ac.id/index.php/hydrogen

Hasan, M., Milawati, Darodjat, Khairani, H., & Tahrim, T. (2021). *Media Pembelajaran [Learning Media]*. Semarang: Tahta Media Group.

Ismail, H., Kasman, R.A., & Fadli, M. (2024). Pengembangan Modul Ajar IPAS Berbasis Masalah (PBL) pada Jurusan Nautika Kapal Penangkapan Ikan [Development of Problem-Based Learning (PBL) Teaching Modules for the Fishing Vessel Navigation Department]. *JRGI: Jurnal Riset Guru Indonesia*, 3(2), 68–75. https://doi.org/10.62388/jrgi.v3i2.437

Istiqomah, I., Masriani, M., Rasmawan, R., Muharini, R., & Lestari, I. (2022). Pengembangan E-Modul Flipbook IPA Berbasis Problem Based Learning pada Materi Pencemaran Lingkungan [Development of Problem-Based Learning-Based Science Flipbook E-Modules on Environmental Pollution Material]. *Jurnal Basicedu*, 6(5), 9156–9169. https://doi.org/10.31004/basicedu.v6i5.3558

Jayanti, M.A., & Pertiwi, K.R. (2023). Pengembangan E-Modul Berbasis PBL untuk Meningkatkan Kemampuan Analisis dan Rasa Ingin Tahu Siswa [Development Of PBL-Based E-Modules to Improve Students' Analytical Skills and Curiosity]. *JINoP (Jurnal Inovasi Pembelajaran)*, 9(1), 112–127. https://doi.org/10.22219/jinop.v9i1.23178

John, G. (2024). Implementation of Innovative Teaching Methods on Enhancing Quality Teaching and Learning In Secondary Shcools in Morogoro Tanzania. *Pedagogik: Jurnal Pendidikan*, 11(2), 264–277. https://doi.org/10.33650.pjp.v11i2.9429

Kautsari, M., Hairida, H., Masriani, M., Rasmawan, R., & Ulfah, M. (2023). Pengembangan E-Modul Berbasis Problem Based Learning pada Materi Zat Adiktif [Development of Problem-Based Learning E-Modules on Addictive Substances]. *Edukatif : Jurnal Ilmu Pendidikan*, 4(6), 8116–8130. https://doi.org/10.31004/edukatif.v4i6.3850

Kharismanda, K., Kuntjoro, S., & Putra, R.N.S.E.T. (2024). Penggunaan Model PBL Terintegrasi Tarl dan KSE dalam Meningkatkan Hasil Belajar Peserta Didik Materi Unsur, Senyawa dan Campuran [The use of Integrated PBL Models Tarl and KSE in Improving Student Learning Outcomes in the Subject Matter of Elements, Compounds, and Mixtures]. *PeTeKa: Jurnal Penelitian Tindakan Kelas dan Pengembangan Pembelajaran*, 7(3), 334–341. http://dx.doi.org/10.31604/ptk.v7i3.334-341

Knopfel, M., Kalz, M., & Meyer, P. (2024). General Problem-Solving Skills can be Enhanced by Short-Time use of Problem-Based Learning (PBL). *Journal of Problem Based Learning in Higher Education*, 12(1), 82–91. https://doi.org/10.54337/ojs.jpblhe.v12i1.7871

Lestari, I., Enawaty, E., & Ulfah, M. (2024). Analisis Kemampuan Siswa Menyelesaikan Soal-Soal Higher Order Thinking Skill pada Materi Laju Reaksi di Kelas XI MAN 1 Pontianak [Analysis of Students' Ability to Solve Higher Order Thinking Skill Questions on Reaction Rate Material in Class XI At MAN 1 Pontianak]. *Hydrogen: Jurnal Kependidikan Kimia*, 12(4), 824–833. https://doi.org/10.33394/hjkk.v12i4.12139

Margalita, S., Susantini, E., Kuntjoro, S., & Ali, M. (2025). Validitas dan Efektivitas E-Book Problem Based Learning Terintegrasi Budaya Lokal untuk Meningkatkan Keterampilan Literasi Digital di Era Masyarakat 5.0 [The Validity and Effectiveness of Locally Integrated Problem-Based Learning E-Books to Improve Digital Literacy Skills in the Era of Society 5.0]. *JIPI (Jurnal IPA & Pembelajaran IPA)*, 9(1), 154–169. https://doi.org/10.24815/jipi.v9i1.42573

Murphy, C., Connell, S., Gantley, M., & Barrett, T. (2025). Students' Perspectives on the Congruence and Effectiveness of a Problem-Based Learning Approach to Teach Recovery-Oriented Practice: A Mixed Method Study. *Nurse Education in Practice*, 84(5), 1–9. https://doi.org/10.1016/j.nepr.2025.104298

Muthia, G.A., & Anggereini, E. (2023). Application of Problem Based Learning Assisted by Reward and Punishment to Improve Self-Regulation of Junior High School Students. *JIPI (Jurnal IPA & Pembelajaran IPA)*, 7(3), 289–301. https://doi.org/10.24815/jipi.v7i3.33203

Nurhikmah, S., Sandy, S., Ali, R.Z., & Ruswandi, U. (2023). Desain Pembelajaran PAI dengan Model ADDIE pada Materi Beriman kepada hari Akhir di SMA Plus Tebar Ilmu Ciparay [PAI Learning Design Using the ADDIE Model for Material on Belief in the Last Day at Ciparay Plus High School]. *Al Qalam: Jurnal Ilmiah Keagamaan dan Kemasyarakatan*, 17(2), 297-303. *https://doi.org/10.35931/aq.v17i2.1988*

Pertiwi, F.A., Luayyin, R.H., & Arifin, M. (2023). Problem Based Learning untuk Meningkatkan Keterampilan Berpikir Kritis: Meta Analisis [Problem-Based Learning to Improve Critical Thinking Skills: Meta-Analysis]. *JSE: Jurnal Sharia Economica,* 2(1), 42–49. https://doi.org/10.46773/jse.v2i1.559

Rahmawati, R., Santoso, H., & Asih, T. (2022). Pengembangan E-Modul Berbasis Problem Based Learning disertai Nilai Karakter pada Materi Ekosistem Kelas X SMA [Development of Problem-Based Learning E-Modules Accompanied by Character Values in Ecosystem Material for 10th Grade High School Students]. *Seminar Nasional Pendidikan IPA, 2022 Juni,* pp.126–137. https://prosiding.ummetro.ac.id/index.php/snpb/article/download/48/29

Riduwan. (2018). *Skala Pengukuran Variabel-Variabel Penelitian [Measurement Scale of Research Variables]*. Bandung: Alfabeta.

Rizaldi, R., Syahwin, & Ramadani. (2022). Efektifitas E-Modul Praktikum Fisika Berbasis Model Problem Based Learning Menggunakan Smart Apps Creator terhadap Keterampilan Proses Sains Siswa SMA/MA [Effectiveness of Physics Practical E-Modules Based on Problem-Based Learning Models using Smart Apps Creator on High School/MA Students' Science Process Skills]. *Jurnal Pendidikan MIPA*, 12(3), 720–725. https://doi.org/10.37630/jpm.v12i3.647

Salsabila, P., Putra, T.P., Nasir, M., Abe, Y., & Linda, R. (2024). Development of Science E-Module Based on Augmented Reality using Assembler Edu on The Material of Substances and their Changes. *JIPI (Jurnal IPA & Pembelajaran IPA)*, 8(4), 473–484. https://doi.org/10.24815/jipi.v8i4.42369

Sari, D.A., Herman, M., Putri, S.D., & Hidayati. (2025). The Impact of Problem-Based Learning (PBL) Module on Critical Thinking Skills on Electrolyte and Nonelectrolyte Solutions. *Hydrogen: Jurnal Pendidikan Kimia*, 13(1), 106-112. https://doi.org/10.33394/hjkk.v13i1.14137

Sugiyono. (2022). *Metode Penelitian Kuantitatif, Kualitatif dan R&D [Quantitative, Qualitative, and R&D Research Methods]*. Bandung: Alfabeta.

Ulfa, S., Irvani, A.I., & Warliani, R. (2024). Pengembangan Modul Ajar Fisika Kurikulum Merdeka [Development of Physics Teaching Modules for the Independent Curriculum]. *Diklat Review: Jurnal Manajemen Pendidikan dan Pelatihan*, 7(1), 51–59. https://doi.org/10.52188/jpfs.v7i1.562

Wahidah, S., Karneli, Y., & Marsidi, S. (2025). Implementasi Konsep Pemikiran Ki Hajar Dewantara di SMP Negeri 2 Kutablang dalam Meningkatkan Motivasi Belajar Siswa [Implementation of Ki Hajar Dewantara's Concept at SMP Negeri 2 Kutablang in Improving Student Learning Motivation]. *Alacrity : Journal of Education*, 5(1), 13–22. https://doi.org/10.52121/alacrity.v5i1.489

Wahyuni, S., Rifqi, A.H., Yusmar, F., & Sya, H. (2025). Development of Module Based on Local Wisdom of Grenden Village to Improve Students Critical Thinking Skills in Junior High School Science Learning. *JIPI (Jurnal IPA & Pembelajaran IPA)*, 9(1), 231–247. https://doi.org/10.24815/jipi.v9i1.44384

Wibisana, I.M.A.P., Suardana, I.N., & Sastrawidana, D.K. (2022). Pengembangan E-Modul Pembelajaran IPA SMP Kelas VII Berbasis Komik Berpendekatan Jelajah Alam Sekitar untuk Meningkatkan Hasil Belajar Siswa [Development of Comic-Based E-Modules for Seventh-Grade Science Learning using an Approach that Explores the Surrounding Environment to Improve Student Learning Outcomes]. *Jurnal Pendidikan Mipa*, 12(3), 700–713. https://doi.org/10.37630/jpm.v12i3.632

Wismath, S., Orr, D., & MacKay, B. (2015). Threshold Concepts in the Development of Problem-Solving Skills. *Teaching & Learning Inquiry: The ISSOTL Journal*, 3(1), 63–73. https://doi.org/10.20343/teachlearninqu.3.1.63

Yulando, S., Sutopo, S., & Franklin, C.T. (2019). Electronic Module Design and Development: An Interactive Learning. *American Journal of Educational Research*, 7(10), 694–698. https://doi.org/10.12691/education-7-10-4

Yulis, P.A.R. & Fauziah, N. (2024). Analisis Kebutuhan Pengembangan Prototype E-Modul Kimia Hijau Terintegrasi TPACK (Technological Pedagogical Content Knowledge) [Analysis of the Need to Develop an Integrated Green Chemistry E-Module Prototype using TPACK (Technological Pedagogical Content Knowledge)]. *Hydrogen: Jurnal Pendidikan Kimia*, 12(6), 1478–1495. https://doi.org/https://doi.org/10.33394/hjkk.v12i6.13879

Yuningsih, N., Rasmawan, R., & Enawati, E. (2023). Pengembangan LKPD Berbasis Problem Based Learing (PBL) pada Materi Unsur, Senyawa dan Campuran [Development of Problem-Based Learning (PBL) Worksheets on Elements, Compounds, and Mixtures]. *Edukatif: Jurnal Ilmu Pendidikan*, 5(5), 1904–1912. https://doi.org/10.31004/edukatif.v5i5.5416