QUANTUM: Jurnal Inovasi Pendidikan Sains, Vol. 16, No. 1, 75-92
p-ISSN : 2086-7328 e-ISSN : 2550-0716
Website: https://ppjp.ulm.ac.id/journal/index.php/quantum/index
DOI: http://dx.doi.org/10.20527/quantum.v16i1

VALIDITY OF PROBLEM-BASED LEARNING TEACHING MODULE TO IMPROVE CRITICAL THINKING OF HIGH SCHOOL STUDENTS ON ATOMIC STRUCTURE MATERIAL

Legendaria Raula Saputri*, Asih Widi Wisudawati
Chemistry Education Study Program, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Sunan Kalijaga
Jl. Laksda Adisucipto, Sleman, Daerah Istimewa Yogyakarta 55281, Indonesia
*corresponding author: asih.wisudawati@uin-suka.ac.id

Abstract. Chemistry learning, particularly in atomic structure, faces challenges due to its conceptual nature and difficulty in observation. Traditional teaching methods, which often render students passive, exacerbate this issue and hinder critical thinking skill development. To address this, a digital teaching module based on problem-based learning (PBL) was developed and designed for easy accessibility anytime and anywhere. This module promotes interactive learning centered on real-world problems, significantly enhancing students' critical thinking abilities. This study employs a research and development (R&D) approach using the ADDIE model (Analyze, Design, Develop, Implement, Evaluate). The analyze stage involved observing the needs of high school chemistry teachers. The design stage included planning materials, creating the module design, and developing assessment instruments. The development stage involved quality evaluations by material experts, media experts, and high school chemistry teachers. Evaluation results showed highly positive feedback, with an ideal score of 93% from material experts, 91.67% from media experts, and an average score of 90.21% from five chemistry teachers, all classified as very good. The module is considered effective and offers an alternative approach to teaching atomic structure. Future studies are recommended to advance this module to the implementation phase, as this research has only reached the development stage.

Keywords: teaching module, problem-based learning, atomic structure

INTRODUCTION

Chemistry is a conceptual science that is often considered difficult to understand due to its abstract nature. Atomic structure is the basis for understanding chemistry learning (Istiqomah et al., 2021; Nofriyanti & Hardeli, 2023) and becomes even more difficult to understand if taught using traditional methods that are less interactive (Dewi et al., 2021; Mahardika et al., 2018; Majid, 2023). This conventional method hinders the development of students' critical thinking skills due to the lack of active involvement in learning, so students tend to get bored. However, chemistry learning in Indonesia is still dominated by conventional, teacher-centered, book-based methods with a one-way approach that makes students passive and provides minimal opportunities to analyze, identify, and propose ideas in solving problems (Huda, 2021; Junanto & Sartika, 2023; Khairunnisa et al., 2022).

As a result, learning motivation decreases, and students' critical thinking skills do not develop optimally. Students' disinterest in this traditional method causes low critical thinking skills (Susanto et al., 2020). Research shows that animation and educational games can increase students' interest and understanding of complex chemical concepts (Hafizah, 2023). Innovation is needed in learning media that is more interesting and meets the needs of today's students (Sari et al., 2022). One effective solution is a digital-based teaching module that is in line with the Merdeka

Published by: Program Studi Pendidikan Kimia FKIP Universitas Lambung Mangkurat
How to Cite: Saputri, L., R., & Wisudawati, A., W. (2025). Validity of Problem-Based Learning Teaching Module to Improve Critical Thinking of High School Students on Atomic Structure Material. *QUANTUM: Jurnal Inovasi Pendidikan Sains*, 16(1), 75–92. http://dx.doi.org/10.20527/quantum.v15i2.18441.

Article History:
Received : 22-01-2025, *Accepted* : 09-04-2025, *Published* : 08-05-2025

Curriculum, which can help educators actively improve students' critical thinking skills through the provisions of the curriculum (Amrullah et al., 2024; Marpaung, 2024). Innovative approaches such as PBL can address these issues by encouraging students to be more active in finding solutions, analyzing information, and connecting theoretical concepts with real-life applications (Hafizah & Nurhaliza, 2021; Rasya et al., 2024). In learning atomic structure, PBL not only helps students understand the material conceptually but also trains analytical and systematic thinking skills in solving complex problems (Hamdani et al., 2022; Haryanti et al., 2023).

Based on empirical data at SMAN 2 Pujut, student learning outcomes on atomic structure material in the 2020 academic year in classes X-IPA1 and XI-IPA2 reached an average of 52.76 and 57.17, with a percentage of completion of 33.33% and 42.85%, respectively, which are still relatively low. Empirical data shows that in atomic structure material, many students have not achieved completion due to internal factors, such as low motivation and understanding of concepts, as well as external factors, such as limited learning resources and less interactive teaching methods (Resti et al., 2024). Effendy (2002) showed that atomic structure is a concept that is difficult for students to understand because of its contextual nature and cannot be seen directly. This is in line with the statement that if difficulties in learning chemistry are not immediately addressed, students can experience misconceptions about the concepts of atoms and molecules being studied (Langitasari et al., 2021).

As a solution, PBL-based teaching modules can be a tool to help teachers support chemistry learning. This module is designed to facilitate students in the learning process by presenting material in a more structured, interactive, and curriculum-based manner. Modern modules are also equipped with interactive features such as videos, images, and external links to increase the effectiveness of material delivery and encourage student involvement in discussions and problem-solving (Hanida et al., 2023). The application of questions in the module and the facilitation of group discussions carried out by teachers can help increase student activity and develop their critical thinking skills. The implementation of questions in the module and group discussions conducted by teachers can help improve student activity and develop their critical thinking skills. The preparation of teaching modules is based on the learning objective flow and learning outcomes. In chemistry learning, many studies of various innovative modules have been developed, such as PBL-based modules for chemical bonds, inquiry in thermochemistry, and STEM on the concept of redox, which has been proven to improve student understanding (Irfandi et al., 2018; Novia et al., 2023; Rokhim et al., 2020).

Therefore, this study aims to develop a PBL-based teaching module to improve critical thinking skills in understanding atomic structures. By implementing project assignments, discussions, and group-based games, PBL allows students to be more active in understanding and applying chemical concepts more deeply and applicatively. This module not only presents contextual problems that are relevant to everyday life but is also equipped with more systematic critical thinking assessment instruments. In addition, interactive features such as virtual learning videos and educational games are applied to increase student involvement in the problem-solving process. This innovation answers the limitations of previous research, which generally still focuses on the application of PBL without technology integration or structured assessment.

This study focuses on the development of a PBL-based atomic structure teaching module to improve students' critical thinking skills, referring to Nasution's (2023) research, which examined the effect of PBL on critical thinking on similar materials. Several previous studies have shown that PBL modules are effective in

improving critical thinking skills and conceptual understanding in science, including chemistry (Handayani et al., 2022a; Sugiarti & Dwikoranto, 2021). However, most studies still focus on the implementation of PBL in general without the development of teaching materials specifically designed to optimize this approach.

The main advantage of this study is the development of a teaching module that not only adopts PBL but also applies it in depth through the integration of real-world problem-based questions and group games that increase student interactivity and engagement. With this approach, the module is designed to strengthen the relationship between the PBL method and atomic structure learning through more contextual and applicable problem-solving. Thus, this study not only examines the feasibility of the teaching module but also contributes to the innovation of teaching materials that are more in line with the needs of 21st-century learning, which emphasizes critical and collaborative thinking skills.

With this approach, this study contributes to the improvement of the application of PBL to atomic structure material through more contextual and real problem-based learning experiences. This module not only helps students understand abstract concepts more deeply but also trains their analytical, evaluation, and problem-solving skills independently. Thus, this study is expected to develop students' critical thinking more optimally.

METHOD

a) Type of Research

Research and Development (R&D). problem-based learning modules that focus on atomic structure material. This study adapts the ADDIE model, which consists of the stages of analysis, design, development, implementation, and evaluation (Indah Mafazatin Nailiah & Erwin Rahayu Saputra, 2022). The ADDIE model has clear, systematic, effective, and efficient steps, making it the right choice. The ADDIE design idea (Latip, 2022) is depicted in Figure 1.

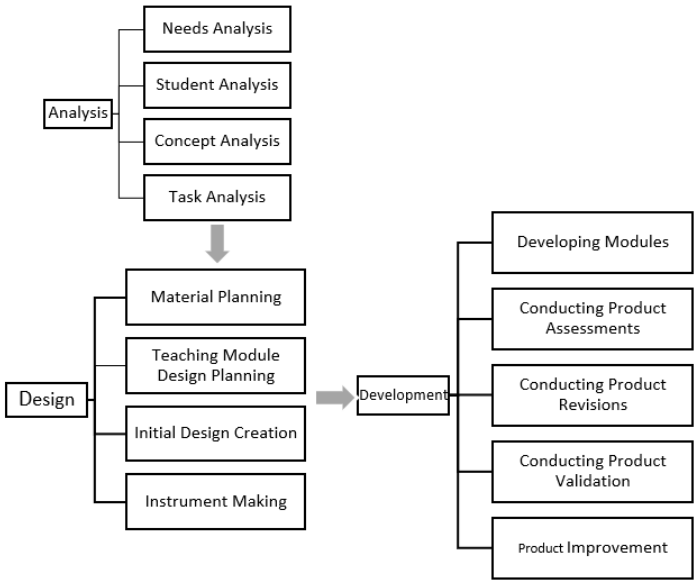


Figure 1. Development steps with the ADDIE model

b) Development Procedures

This development research procedure consists of four stages as follows:

1) Analysis

At this stage, the researchers assisted in determining and explaining the needs of high school teachers and collecting information related to things that was being developed in the products made through observation. Needs analysis, concept analysis, and task analysis were the activities carried out.

2) Design

This stage involved planning materials, planning teaching module designs, making initial designs, and making instruments.

3) Development

This stage aims to collect information about product quality assessment from material experts, media experts, and high school chemistry teachers. This stage included activities to create teaching modules and then conduct validation tests on various competent parties in the fields of material, media, and educators (Waruwu, 2024). In addition, the interview was conducted with high school chemistry teachers to obtain more in-depth input. This study only reached the stage of developing an open module. Time limitations in aligning the module content with the school curriculum hindered the process, as it requires teacher training, material preparation, and adaptation to new methods. Therefore, the implementation and evaluation stages of the module could not be carried out. Further research is needed to assess the effectiveness of the module in enhancing students' critical thinking skills.

c) Research Subjects

One material expert, one media expert, and a reviewer (a chemistry teacher in grade X of high school) were the subjects of this study.

d) Techniques and Instruments

In this study, data were collected through interviews and assessments of media experts, material experts, and teacher assessments. The tools used included material expert validation sheets, media expert validation sheets, chemistry teacher assessment sheets, and structured interview questions for chemistry teachers in high schools.

e) Data Analysis

Product validation data consisted of qualitative data entered from product trial subjects, which is then converted into quantitative data using the Likert scale shown in Table 1.

Table 1. Likert scale categories

No	Category	Scale	Score
1.	Very Good	VG	4
2.	Good	G	3
3.	Poor	P	2
4.	Very Poor	VP	1

Pradana & Mawardi (2021)

Next, the validation score was calculated using the following equation:

$$\text{bar equals } \bar{X} = \frac{\Sigma X}{N} \qquad (1)$$

Information:

$\bar{X}$ = average score

Σx = total score

N = number of assessments

Then, the average score for the whole and each assessment component was calculated. Next, according to the ideal assessment category, these values were converted into qualitative values (Jodi & Yuwaningsih, 2023), as shown in Table 2.

Table 2 Ideal assessment criteria

Range of Score	Category
$x \geq (\bar{x} + 1.SBi)$	Very Good
$(\bar{x} + 1.SBi) > x \geq \bar{x}$	Good
$\bar{x} > x > (\bar{x} - 1.SBi)$	Poor
$x < (\bar{x} - 1.SBi)$	Very Poor

Information :
X = Average
$\bar{x}$ = Average ideal score
$= \frac{1}{2}(ideal\ maximum\ score + ideal\ minimum\ score)$
SBi = Standard deviation of ideal score
$= \frac{1}{6}(ideal\ maximum\ score - ideal\ minimum\ score)$
Skor maksimal ideal = Σ criteria items × highest score
Skor minimal ideal = Σ criteria items × lowest score

$$\text{Ideal Presentation} = \frac{score\ achieved}{ideal\ maximum\ score} x\ 100\% \quad (2)$$

The data collection technique used three methods, namely observation by seeing and observing the actual situation, a questionnaire method in the form of a statement as an assessment tool to ensure that the teaching module that has been developed is feasible and provides maximum benefits for teachers, and interviews that can help evaluate whether the teaching module is feasible in supporting learning. Data from the questionnaire was confirmed through interviews to ensure the suitability and consistency between quantitative and qualitative data.

RESULTS AND DISCUSSION

This study introduces a problem-based atomic structure teaching module that uses atomic structure material to improve students' critical thinking skills. In addition to the fact that atomic material is often considered difficult due to its abstract nature, this teaching module takes atomic structure material because it introduces regularity in the arrangement of atom particles and the periodic system of elements reflects the balance of nature. By understanding this concept, students not only develop scientific insight but also realize that the regularity underlying the laws of nature is His decree. This teaching module was chosen because of its interactive design and problem-based approach, which allows students to understand the concept more easily. In addition, this teaching module functions as an effective learning aid and serves as a guide for teachers and students in their learning process (Sodik et al., 2023). The advantage of this teaching module lies in the application of a problem-based approach, which can stimulate critical thinking, deepen understanding of concepts, and encourage active student participation during the learning process. Problem-based learning modules have been shown to improve critical thinking skills by teaching students to find solutions, analyze data, and make decisions on their own (Latip, 2022). Previous studies have shown that problem-based learning modules improve students' learning outcomes and critical thinking skills (Ismanida et al., 2023; Lestari & Yerimadesi, 2024; Mufida et al., 2022a; Rohmatulloh et al., 2023).

Analysis Stage: The first stage of the ADDIE model is analysis, which aims to identify and define development requirements. The requirements in question are

something that can show the basic needs of why the teaching module learning device needs to be developed (Adnyana & Yudaparmita, 2023). This requires 4 different analyses to find the main problem. At this point, the problems analyzed by the researchers included needs analysis, student analysis, concept analysis, and task analysis.

The researchers interviewed chemistry teachers to find out their needs. According to the interview, teachers have never used problem-based learning modules as a learning tool. So far, the media used are only printed books and PowerPoint. In addition, educators stated that they face challenges in creating interactive learning modules that are based on the problem-based approach. They believe they cannot create modules that will interest students and improve their critical thinking skills. In addition, textbooks are usually too complex, so students have difficulty understanding the material independently. The PowerPoint media used is still less effective in explaining conceptual concepts such as atomic structure because it tends to be monotonous and too teacher-centered if it only relies on this media. The interview results also revealed that the use of existing learning devices still makes learning more teacher-centered and does not facilitate active student involvement.

Analysis of interviews with the teachers shows that students tend to get bored with monotonous learning models, so a more interactive and innovative approach is needed to increase their engagement in learning. Problem-based learning models are considered a solution because they can increase student engagement in the learning process and their ability to think critically (Sucipta et al., 2023).

Concept analysis was carried out by referring to core competencies, learning outcomes, and learning objective flow to determine the scope of the material to be taught, namely atomic structure. Analysis core competencies, learning outcomes, and learning objective flow was carried out to determine the limits of the material to be delivered, namely atomic structure material that requires strong critical thinking skills. The aim is to ensure that the material delivered is in line with the competencies expected of students so that atomic structure material can be achieved optimally. The expected result is that students can explain in detail the particles that make up atoms (protons, neutrons, and electrons), explain the development of various atomic models (Dalton, Thomson, Rutherford, Bohr), understand the concept of atomic particles and atomic notation, understand the electron configuration of Bohr atoms, and introduce nanotechnology.

Task analysis was carried out by explaining core competencies, learning outcomes, and the flow of learning objectives into learning objectives. The learning objectives developed in this teaching module include (1) being able to realize the existence of regularity in atoms as a manifestation of the greatness of God Almighty. (2) Being able to compare the development of atomic theory starting from Dalton's atomic theory to quantum mechanics. (3) Being able to determine the number of protons, electrons, and neutrons of an atom based on its atomic number and mass number. (4) Being able to determine isotopes, isobars, and isotones of several elements. (5) Being able to explain the atomic structure of the Bohr atomic model and write the electron configuration of the Bohr atomic model. (6) Being able to describe the meaning and importance of nanotechnology through discussion activities and examples of its application in everyday life.

Design stage: At this stage, the researchers carried out the task of creating, compiling, and designing a conceptual framework based on existing theories. They also create a tool to find out whether the learning module is valid, practical, and

useful, namely the validation sheet. A brief description of the design of the learning module developed is as follows:

1) Material Planning

   At this time, the researchers prepared references that are by the material in the form of atomic structures. These references were used when building learning modules based on the independent curriculum. Furthermore, the format and display design are selected using Microsoft Office Word. The material to be studied in this learning tool is atomic structure, which consists of several sub-materials, such as atomic particles (protons, neutrons, electrons), explanations of the development of various atomic models (Dalton, Thomson, Rutherford, Bohr), understanding the concept of atomic particles, atomic notation, understanding Bohr's electron configuration, and reducing atomic particles into smaller atoms.

2) Teaching Module Design Planning

   Product design planning was designed according to the learning material chosen by the researchers, namely the form of atomic structure. The independent curriculum-based teaching module that is designed includes 1) Module Cover, 2) Module Identity, 3) Core Competencies, 4) CP and TP, 6) Learning Objective Flow (ATP), 7) Initial Competencies, 8) Learning Activities, 9) Attitude Domain Assessment, 10) Student worksheet, 11) Assessment, Evaluation, and Reflection,

3) Initial Design Creation

   The software used in this study included Microsoft Word and Canva applications. Microsoft Word makes it easy to write, edit, and format text and supports visual elements such as images and tables. Headings help organize modules neatly, while the export to PDF option makes distribution easier. Canva provides a variety of ready-to-use templates that are professionally designed, so teachers can choose a design that suits the theme or needs of the teaching module. In addition, Canva offers an extensive library of images, icons, fonts, and other graphic elements that can be used to enrich module content (Napitupulu et al., 2024).

4) Instrument Making

   The instruments that have been made were first consulted with the supervising lecturer and then validated. The research instruments include validation, material assessment, product quality assessment, teacher reviewers, and structured interview questions. The material assessment instruments include aspects of material feasibility, linguistic aspects, presentation aspects, and critical thinking aspects. The product quality assessment instruments include aspects of design, graphics, and use. The teacher reviewer instruments include aspects of the content of the teaching module, linguistic aspects, presentation, and critical thinking. Interview questions are arranged to deepen the answers to the questionnaire given to teachers. The instruments that have been made have been validated by instrument experts.

D*evelopment Stage*: At the development stage, the plans and designs that have been prepared at the design stage were realized into a product, and then the product goes through a validation process by experts (materials, media, high school chemistry teachers) and interviews with high school chemistry teachers. The activities carried out at this stage are the creation of products in the form of teaching modules. The following are the stages of its creation.

The first stage was to prepare the Microsoft Word display in the office and prepare the atomic structure material that was displayed in the teaching module. The second stage was editing by entering the cover, module identity, and student worksheet which can be seen in Figure 2.

The PBL steps in the atomic structure teaching module based on critical thinking include identifying basic competencies and learning objectives, designing contextual problems, and learning based on independent and collaborative investigation. Students identify problems, formulate hypotheses, and seek solutions based on scientific evidence. The results of the analysis are presented in reports, discussions, or presentations, then evaluated through question-based reflection and assessment to measure understanding and critical thinking skills.

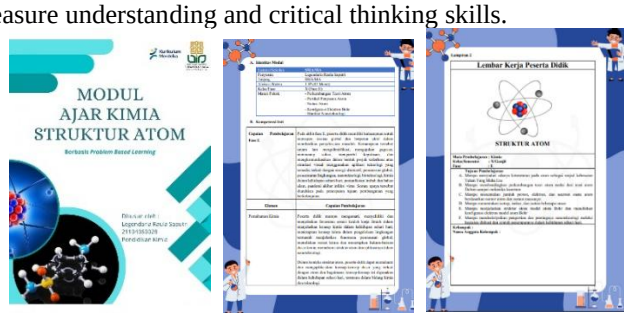


Figure 2. Process of making learning module teaching devices

This stage is carried out by selecting and creating a background that aims to foster interest in the developed teaching module (Angresia et al., 2022), and Canva to design the visual elements of the module. Choose a suitable template or create a design from scratch. Make sure to use fonts that are easy to read and consistent with an attractive color theme. Add graphic elements such as illustrations, icons, or diagrams to strengthen the delivery of information.

The teaching module that has been created is then equipped to design the syntax of problem-based learning related to atomic structure material that begins with apperception. Apperception in the teaching module is related to everyday life events that can reduce boredom in learning, then educational games via https://phet.colorado.edu/in/simulations/build-an-atom help attract students' attention, provide context, and increase their motivation and understanding, and PowerPoint was used to explain the material. This stage can be seen in Figure 3.

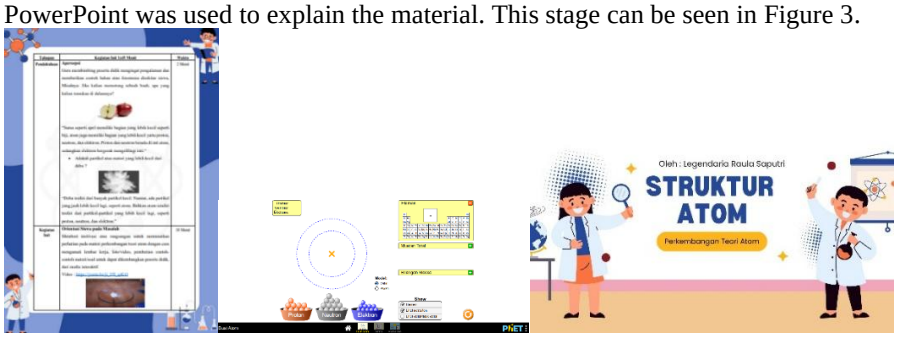


Figure 3. Process of editing learning module learning devices

The contents of the teaching module are an explanation of the atomic structure consisting of 1) the development of atomic theory and 2) particles that make up atoms 3) atomic notation 4) Bohr electron configuration 5) benefits of nanotechnology 6) daily, summative, remedial, and enrichment assessment questions; project assessment

6) attitude domain assessment 7) student worksheet 8) reflection for teachers and students. This can be seen in the following Figure 4.

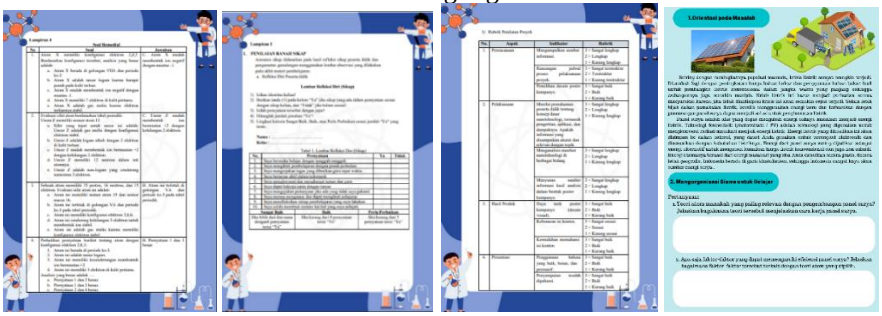
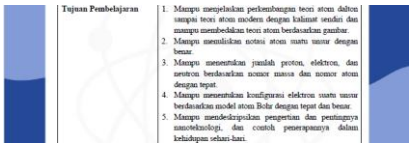
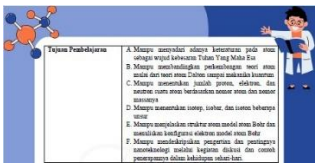
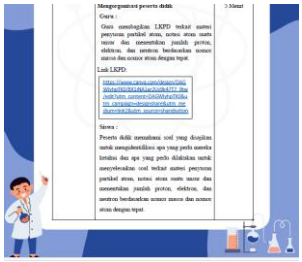
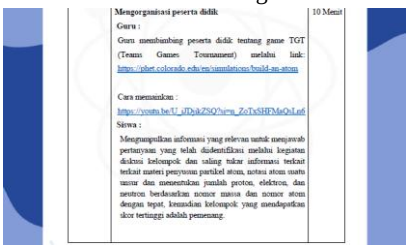
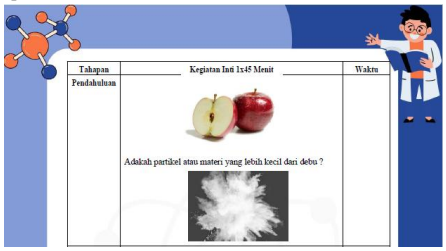
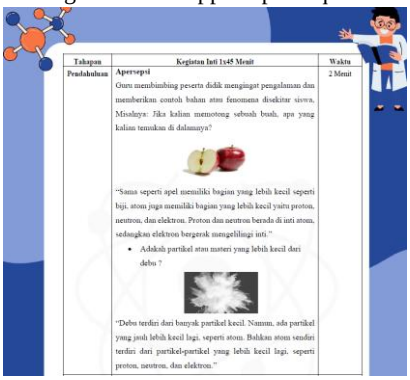


Figure 4. Display of the contents of the teaching module

Several revisions to the problem-based learning teaching module are based on suggestions and input from validators to obtain a better product:

Before Revision	After Revision
Learning objectives still use numbering 	Separate learning objectives into using letters 
The use of media is less varied 	Add educational games 
There is no answer to the apperception question 	Adding answers to apperception questions 

After the teaching module was created, a research instrument was created. The instrument that had been created was first consulted with the supervising lecturer and

then validated. The research instrument included material validation, product quality assessment, and teacher review. The material assessment instrument included aspects of material feasibility, language aspects, presentation aspects, and critical thinking aspects. The product quality assessment instrument included aspects of design, graphics, and use. The teacher reviewer instrument included aspects of the content of the teaching module, language, presentation, and critical thinking. Interview questions were prepared to deepen the answers to the questionnaire given to the teacher. The instrument that had been created had been validated by an instrument expert. The finished product would be validated by a validator (material expert, media expert, and high school chemistry teacher). The validator is an expert or practitioner who validates the media that was developed based on the aspects mentioned in the questionnaire. Validation was carried out until the media is said to be feasible or valid for use as a learning medium. The following are the validation results from media expert lecturers, material experts, and high school chemistry teachers.

Material experts and media experts have important roles in the validation process of learning media. Material experts are responsible for validating media in terms of material content and learning quality, while media experts focus on validation in terms of language and format. The feasibility test of materials and media is carried out by experts who are lecturers from the Chemistry Education Study Program of UIN Sunan Kalijaga Yogyakarta.

In the problem-based learning teaching module on atomic structure material, the critical thinking indicators developed by Ennis (1985) emphasize aspects of analysis, evaluation, and problem-solving. These indicators are in line with the PBL approach, which requires students to identify problems, examine relevant information, and develop solutions based on logical and systematic thinking.

The following are the results of the analysis of the quality assessment of teaching module products according to material expert lecturers, which can be seen in Table 3.

Table 3. Product quality assessment by material and media experts

Assessment Aspect	ΣScore	ΣIdeal Maximum Score	Ideal Percentage	Category
Material suitability	16	16	100%	Very Good
Language	14	16	87.5%	Very Good
Presentation	10	12	83.3%	Very Good
Critical Thinking	16	16	100%	Very Good
Design	17	20	85%	Very Good
Graphics	19	20	95%	Very Good
Use	8	8	100%	Very Good

Table 3 shows the evaluation results of the material experts and media experts on the teaching module. Based on the results of the data processing analysis, the material experts obtained a total score of 56 out of 60, which resulted in an ideal percentage of 93%. Based on the descriptive analysis assessment criteria table that has been explained in the method section, this percentage is in the 'very good' category. Meanwhile, the results of the media expert evaluation of the teaching module showed a total score of 44 out of 48, with an ideal percentage of 91.67%. Based on the same assessment criteria, this percentage is also in the 'very good' category.

Based on the validation of material experts and media experts above, the average validator assessment shows very good results. This shows that the quality of

the atomic structure material teaching module developed meets the pedagogical elements and good learning media and is by the target user, namely teachers. However, there are several criticisms and suggestions from validators for revisions so that the product developed becomes a better product.

The teaching module on atomic structure material has been validated and revised according to comments and suggestions from experts and then tested for practicality by chemistry teachers. The teacher's role is to assess learning tools from the aspects of material content, language, presentation, and critical thinking. Product assessment was carried out by five high school chemistry teachers. The results of the analysis of the quality assessment of teaching module learning device products according to high school chemistry teachers can be seen in Table 4.

Table 4. Product quality assessment by chemistry teachers 1-5

Assessment Aspect	Σ Ideal Maximum Score	1	2	3	4	5
Fill	48	48	47	43	41	41
Language	16	15	16	14	12	12
Presentation	16	16	16	15	16	12
Critical Thinking	16	16	16	14	12	13
Σ Score	96	95	95	86	81	78
Ideal Presentation (%)	100	98	98	89.5	84.3	81.25
Category	**Very Good**	**Very Good**	**Very Good**	**Very Good**	**Very Good**	**Very Good**

Based on the results of the data processing analysis, a total score of 95 was obtained with an ideal percentage of 98% twice. Furthermore, the assessment results on the atomic structure material teaching module showed a score of 86 with an ideal percentage of 89.5%. Likewise the assessment results on the next teaching module, which obtained a total score of 81 with an ideal percentage of 84.3%. In the last assessment, a total score of 78 was obtained with an ideal percentage of 81.25%. These results indicate that the assessment of the atomic structure material teaching module is recorded in the 'very good' category based on the descriptive analysis assessment criteria table explained in the method section.

In general, the response from validators to the capabilities of learning media in the form of teaching modules on atomic structure material was very positive. Validation was carried out by the researchers involving media experts, material experts, and high school chemistry teachers. In line with research conducted by Sugianto, (2024), the use of this learning tool is considered feasible because it functions as the main guide in the learning process, which is designed to help teachers and students achieve learning goals effectively. For teachers, teaching modules provide a systematic framework in the form of activity plans, materials, methods, and evaluations that can be followed or modified according to student needs and class conditions. This module also functions as a tool that makes it easier for teachers to manage time and organize learning steps in stages.

Based on validation and opinions from validators, it can be concluded that the main role of the atomic structure teaching module is to attract students' attention to conceptual material such as atomic structure, as well as help them understand concepts through the context of real problems. This teaching module also plays a role in encouraging students to develop critical thinking skills by relating the concept of atomic structure to real-world applications, such as nanotechnology, so that students not only understand the theory but are also able to analyze, evaluate, and formulate

solutions to the problems given. In addition, teaching modules enrich students' learning experiences by providing varied, interactive, and contextual activities, which are difficult to achieve with traditional textbook-based learning methods.

Based on the results of interviews with teachers, this teaching module is considered capable of exploring the concept of atomic structure to a deep level of understanding for students. This is due to the presence of trigger questions and real-life phenomena that encourage students to think critically and scientifically. In addition, this module also provides applied examples, such as the relationship between atomic theory and the Lapindo mud case, so that students can understand chemical concepts in a real-world context. In terms of suitability with the curriculum, this module has met the learning outcomes and objectives set.

Furthermore, the results of interviews with five teachers showed that the student worksheet, questions, and learning flow in the module were based on the problem-based learning (PBL) learning model. This indicates that this module supports problem-solving-based learning that can improve students' critical thinking skills. Although this module cannot be declared effective because it has not been implemented directly, the results of interviews and questionnaires show that this module is quite feasible to use in the learning process. Based on information from informants in interviews:

"In addition, this module is effective in encouraging students to think critically by relating the concept of atomic structure to nanotechnology applications, especially when combined with critical questions and the use of visual illustrations such as color television images. This module is also considered to have the potential to develop critical thinking skills, such as analyzing, evaluating, and formulating solutions, and the problem-based learning (PBL) approach applied has been quite successful in improving students' critical thinking skills in understanding complex concepts."

This teaching module research produced findings that were consistent with previous research conducted by Mufida (2022), which showed that PBL-based teaching modules were effective in improving students' critical thinking skills (Mufida et al., 2022b). The similarity of these results confirms that the tested teaching module is worthy of being applied in the learning process because it supports a problem-solving-based approach that has been proven to be able to deepen understanding of the concept of atomic structure.

The evaluation aspect of the module includes critical thinking skills by assessing student performance through presentations, projects, and discussions. Based on information from informants in interviews:

"Varied and interesting learning activities are considered capable of actively involving students. Evaluation questions are also considered good because they provide open-ended and contextual questions that encourage students to reason. Overall, this module is by the PBL concept because the learning steps, problem selection, and evaluation questions have been well designed. The visual appearance of the module, such as pictures and graphs, is also considered interesting and able to support student understanding. The language used is quite easy to understand; there are no technical terms that need to be simplified, and components in the module such as learning objectives, materials, activities, and evaluation are covered completely."

In terms of ease of use, this module is flexible and easy to adapt to student characteristics and learning conditions in the classroom. Teachers also feel that this module makes the daily learning process easier, although additional variations are needed according to the level of students' thinking abilities. Based on information from informants in interviews:

"Compared with the previous module, the advantages lie in the use of more varied learning media and more attractive visuals, although there are shortcomings in the material, which is considered not completely comprehensive. For future improvements, it is recommended that this module add more varied supporting components and strengthen essential material that is important to base the next learning phase on. Overall, this module is considered quite effective, but it would be better with slight improvements to the material and the addition of supporting components."

The research results obtained through interviews show that the atomic structure teaching module is suitable for use in the learning process. Several factors support this. First, the content of the teaching module is structured to suit student needs, which are identified through theory-based needs analysis using the ADDIE model. Other research also shows that teaching modules developed using the ADDIE model are effective in supporting learning for students and teachers (Sahaat et al., 2020). Apart from that, research results (Mashami & Khaeruman, 2020; Robiah et al., 2024) reveal that the teaching module is based on problem-based learning on atomic structure material. Improving students' critical thinking skills that have been developed can help students in the learning process and make understanding the material easier.

Second, the use of teaching modules in the learning process accompanied by games can facilitate understanding and strengthen students' memory by linking atomic structure material with students' daily activities. This teaching module is designed to help educators carry out learning, simplifying, expediting, and improving the quality of learning, becoming a reference for teachers in carrying out learning activities, and becoming a framework that describes procedures and organizing learning, teaching modules are guidelines that help educators to achieve their goals. Learning and growing the Pancasila Student Profile. Teaching modules can also help students to learn independently with or without teacher guidance. The components in the teaching module are determined by the educator based on their needs. Teaching modules can contain files, discussions, assignments, quizzes, and other learning materials. One of the advantages of PBL-based teaching modules is their ability to encourage active student involvement in the learning process. By being faced with real problems related to atomic structure, students are motivated to search for information, discuss, and work together to find solutions. In this case, PBL-based teaching modules for atomic structure material have the advantage of honing students' critical thinking skills.

Several studies support the use of problem-based learning (PBL) teaching modules because PBL-based teaching modules can facilitate the learning process for students (Handayani et al., 2022b). Previous research (Suswati, 2021) has shown that PBL can increase students' active involvement in the learning process. Through PBL, students are more actively involved in solving real problems, so that their critical thinking and collaboration skills develop better compared to conventional learning methods, where students tend to be more passive (Aldwinarta et al., 2024). This is in line with the findings of Sari et al., (2022) which show that PBL creates a more enjoyable learning environment. This positive impact becomes more evident when educators utilize PBL-based teaching modules, which, as explained by Suswanti (2021), can stimulate critical thinking, active involvement, and students' ability to analyze and solve problems through relevant learning (Suswati, 2021). The advantage of this teaching module lies in its different approach to conventional learning methods which tend to be passive. Problem-Based Learning (PBL) modules offer a more interactive and student-centered approach. Students not only receive information but

also actively participate in the learning process in PBL. This method allows students to gain a deeper and more sustainable understanding of atomic structure ideas.

The use of the ADDIE model in developing teaching modules is considered the right choice. The process of developing a teaching module uses the steps that have been set out in the ADDIE model. The results of each stage can be used as a basis for the next stage, providing a comprehensive framework. Research by Iskandar and Wahab (2023) showed that the ADDIE model is more appropriate for developing learning tools in the I(skandar & Wahab 2023). This is because each stage in the ADDIE model has clear goals and outcomes, allowing developers to follow a systematic and measurable process. The ADDIE model also encourages expert involvement in the evaluation and revision process, ensuring that the final product meets expected quality standards. Thus, products can be revised based on expert assessments, input, and suggestions. The obstacle faced in the product development process is at the implementation stage, which must be adjusted to the learning time at school. This adjustment requires careful planning so that the teaching modules can be used effectively without disturbing the established learning schedule and duration.

The implications of this study indicate that the development of PBL-based teaching modules can be an effective strategy for improving students' critical thinking skills, especially in chemistry learning. Therefore, educators and curriculum developers can consider integrating the PBL model into open materials for other materials in chemistry or other science subjects. As a recommendation for further research, a trial of the implementation of this teaching module is needed on a wider scale to empirically demonstrate its effectiveness in improving student learning outcomes. In addition, further research can explore the influence of this module on other aspects, such as learning motivation, problem-solving skills, or students' collaborative abilities. Further adjustments and developments can also be made by integrating more comprehensive technology or evaluation methods to improve the effectiveness of the module in supporting PBL-based learning.

CONCLUSION

Based on the results of this study, it can be concluded that the development of a Problem-Based Learning (PBL)-based teaching module on atomic structure material has succeeded in meeting the research objectives. The developed teaching module has proven effective in improving students' critical thinking skills by solving problems based on real cases. This approach encourages students to think analytically, seek information, and work together to find solutions. The development of the module uses the ADDIE model until the development stage, resulting in a systematic learning device that is to students' needs. The quality of this teaching module was validated by material experts (93%), media experts (91.67%), and chemistry teachers (90.21%), indicating that this module is worthy of being used as an alternative to learning atomic structure in the class. This module not only covers basic concepts such as atomic theory, particles that make up atoms, and electron configurations but also covers the benefits of nanotechnology in everyday life, making it more contextual and relevant to students. The implications of this study are practical and theoretical. Practically, this module can be an innovative learning resource that not only helps students understand abstract concepts but also develops critical thinking, communication, and collaboration skills as part of 21st-century skills. Therefore, it is recommended that teachers receive training in integrating this module with the curriculum so that its implementation runs optimally. Theoretically, this study contributes to the refinement of the PBL model in chemistry learning by showing that the integration of contextual

problems and interactive technology can increase student engagement and learning effectiveness. Further research can test the effectiveness of this module in covering a wider range and radiating its impact on other aspects, such as student learning motivation and creativity. In addition, the development of a PBL-based module with a digital interactive approach can be a potential research direction to enrich innovation in chemistry learning.

REFERENCES

Adnyana, K. S., & Yudaparmita, G. N. A. (2023). Peningkatan Minat Belajar IPAS Berbantuan Media Gambar Pada Siswa Sekolah Dasar. *Edukasi: Jurnal Pendidikan Dasar*, *4*(1), 61. https://doi.org/10.55115/edukasi.v4i1.3023

Aldwinarta, F. H., Nurdiana, R., & Sulistina, O. (2024). Media Pembelajaran Berbasis *AI Chatbot* pada Materi Termokimia di SMA Apakah Dibutuhkan? *Jurnal Inovasi Pendidikan Kimia*, *18*(1), 1–6. https://doi.org/10.15294/jipk.v18i1.49044

Amrullah, J. D. R., Prasetya, F. B., Rahma, A. S., Setyorini, A. D., Salsabila, A. N., & Nuraisyah, V. (2024). Efektivitas Peran Kurikulum Merdeka terhadap Tantangan Revolusi Industri 4.0 bagi Generasi Alpha. *Jurnal Pendidikan dan Pembelajaran Indonesia (JPPI)*, *4*(4), 1313–1328. https://doi.org/10.53299/jppi.v4i4.754

Angresia, Y., Sesmiarni, Z., Charles, C., & Melani, M. (2022). Komik Digital: Media Pembelajaran Pemrograman Dasar di SMK Negeri 1 Ampek Nagari. *Intellect : Indonesian Journal of Learning and Technological Innovation*, *1*(2), 219–235. https://doi.org/10.57255/intellect.v1i2.204

Dewi, K., Pratisia, T., & Putra, A. K. (2021). Implementasi Pemanfaatan Google Classroom, Google Meet, dan Instagram dalam Proses Pembelajaran Online Menuju Abad 21. *Jurnal Integrasi dan Harmoni Inovatif Ilmu-Ilmu Sosial*, *1*(5), 533–541. https://doi.org/10.17977/um063v1i5p533-541

Hafizah, E., & Nurhaliza, S. (2021). Implementasi *Problem Based Learning* (PBL) Terhadap Kemampuan Literasi Sains Siswa. *Quantum: Jurnal Inovasi Pendidikan Sains*, *12*(1), 1. https://doi.org/10.20527/quantum.v12i1.9497

Hafizah, N. (2023). Media Pembelajaran Digital Generasi *Alpha Era Society 5.0* Pada Kurikulum Merdeka. *Al-Madrasah: Jurnal Pendidikan Madrasah Ibtidaiyah*, *7*(4), 1675. https://doi.org/10.35931/am.v7i4.2699

Hamdani, A. D., Nurhafsah, N., & Rustini, T. (2022). Pengaruh Penerapan Model *Problem Based Learning* (PBL) dalam Pembelajaran IPS terhadap Kemampuan Berpikir Tingkat Tinggi (HOTS) pada Siswa Sekolah Dasar. *Journal on Education*, *5*(1), 460–468. https://doi.org/10.31004/joe.v5i1.620

Handayani, D., Anwar, Y. A. S., Junaidi, E., & Hadisaputra, S. (2022a). Pengembangan Modul Pembelajaran Kimia Materi Asam Basa Berbasis *Problem Based Learning* (PBL) untuk Meningkatkan Motivasi Belajar Siswa. *Chemistry Education Practice*, *5*(1), 107–114. https://doi.org/10.29303/cep.v5i1.2765

Handayani, D., Anwar, Y. A. S., Junaidi, E., & Hadisaputra, S. (2022b). Pengembangan Modul Pembelajaran Kimia Materi Asam Basa Berbasis *Problem Based Learning* (PBL) untuk Meningkatkan Motivasi Belajar Siswa. *Chemistry Education Practice*, *5*(1), 107–114. https://doi.org/10.29303/cep.v5i1.2765

Hanida, J. R., Rachmadiarti, F., & Susantini, E. (2023). Pengembangan E-modul Pembelajaran Ekosistem Berbasis Masalah. *Jurnal Inovasi Pembelajaran Biologi*, *4*(1), 22–38. https://doi.org/10.26740/jipb.v4n1.p23-38

Haryanti, I., Kurniawati, Y., & Lubis, F. H. (2023). Penerapan Virtual Laboratory dengan Menggunakan Model *Problem Based Learning* (PBL) untuk Mendukung Proses Pembelajaran Kimia. *Journal of Chemistry Education and Integration*, *2*(1), 42. https://doi.org/10.24014/jcei.v2i1.21771

Huda, M. (2021). Pemetaan Materi Sastra dalam Buku Pelajaran Bahasa Indonesia Sekolah Menengah Pertama. *KREDO : Jurnal Ilmiah Bahasa dan Sastra*, *4*(2), 293–310. https://doi.org/10.24176/kredo.v4i2.5900

Indah Mafazatin Nailiah & Erwin Rahayu Saputra. (2022). Pengembangan Media ICT Berbasis Video Animasi pada Pembelajaran Bahasa Indonesia dI SD. *JIPD (Jurnal Inovasi Pendidikan Dasar)*, *6*(1), 8–15. https://doi.org/10.36928/jipd.v6i1.976

Irfandi, I., Linda, R., & Erviyenni, E. (2018). Pengembangan Modul Pembelajaran Kimia Berbasis *Learning Cycle – 5E* pada Materi Ikatan Kimia. *EduChemia (Jurnal Kimia dan Pendidikan)*, *3*(2), 184. https://doi.org/10.30870/educhemia.v3i2.3348

Iskandar, I., & Wahab, W. (2023). Pengembangan Perangkat Pembelajaran dengan Model Assure. *Jurnal Konseling Pendidikan Islam*, *4*(1), 152–157. https://doi.org/10.32806/jkpi.v4i1.309

Ismanida, D. P., Enawaty, E., Lestari, I., Erlina, E., & Ulfah, M. (2023). Pengembangan E-modul Laju Reaksi Menggunakan Model *Problem Based Learning*. *EDUKATIF : JURNAL ILMU PENDIDIKAN*, *4*(6), 8251–8261. https://doi.org/10.31004/edukatif.v4i6.3903

Istiqomah, W., Rahayu, S., & Muchson, M. (2021). Identifikasi Miskonsepsi Materi Ikatan Kovalen pada Mahasiswa Kimia Tahun Pertama Universitas Negeri Malang Menggunakan *Tes Diagnostik Two-Tier*. *Jurnal MIPA dan Pembelajarannya*, *1*(6). https://doi.org/10.17977/um067v1i6p482-492

Jodi, J., & Yuwaningsih, D. A. (2023). Pengembangan E-LKPD Trigonometri Berbasis *Problem Solving*. *Hipotenusa Journal of Research Mathematics Education (HJRME)*, *6*(1), 01–21. https://doi.org/10.36269/hjrme.v6i1.1386

Junanto, T., & Sartika, R. P. (2023). Pengembangan Model Pembelajaran Sains Berorientasi Literasi Sains bagi Mahasiswa Calon Guru Kimia. *Hydrogen: Jurnal Kependidikan Kimia*, *11*(5), 759. https://doi.org/10.33394/hjkk.v11i5.8886

Khairunnisa, K., Saadi, P., & Leny, L. (2022). Implementasi Model *Problem-Based Learning* Berbasis STEM dengan Media *Virtual Reality* terhadap Kemampuan Berpikir Kritis dan Self-Regulation Peserta Didik. *Quantum: Jurnal Inovasi Pendidikan Sains*, *13*(1), 96. https://doi.org/10.20527/quantum.v13i1.12109

Langitasari, I., Rogayah, T., & Solfarina, S. (2021). *Problem-Based Learning* (PBL) pada Topik Struktur Atom: Keaktifan, Kreativitas, dan Prestasi Belajar Siswa. *Jurnal Inovasi Pendidikan Kimia*, *15*(2), 2813–2823. https://doi.org/10.15294/jipk.v15i2.24866

Latip, A. (2022). Penerapan Model Addie dalam Pengembangan Multimedia Pembelajaran Berbasis Literasi Sains. *DIKSAINS : Jurnal Ilmiah Pendidikan Sains*, *2*(2), 102–108. https://doi.org/10.33369/diksains.2.2.102-108

Lestari, T., & Yerimadesi, Y. (2024). Validitas dan Praktikalitas E-Modul Interaktif Berbasis *Guided Discovery Learning* pada Materi Sistem Periodik Unsur untuk Fase E SMA. *SCIENCE : Jurnal Inovasi Pendidikan Matematika dan IPA*, *4*(4), 420–431. https://doi.org/10.51878/science.v4i4.3491

© 2025 QUANTUM: Jurnal Inovasi Pendidikan Sains

Mahardika, E., Nurbaity, N., Ridwan, A., & Rahmawati, Y. (2018). Analisis Struktur Kognitif Siswa Dengan Metode *Flowmap* Dalam Materi Asam Basa Menggunakan Model *Learning Cycle 8E*. *EduChemia (Jurnal Kimia dan Pendidikan)*, *3*(1), 51. https://doi.org/10.30870/educhemia.v3i1.1849

Majid, M. A. (2023). Koagulasi Nilai: Pemikiran Membangun Budaya Mutu Madrasah (Suatu Ikhtiar Epistemologis Memajukan Lembaga Pendidikan Islam). *Journal of Nusantara Education*, *3*(1), 39–50. https://doi.org/10.57176/jn.v3i1.82

Marpaung, R. W. (2024). Implementasi Merdeka Belajar dalam Meningkatkan Kreativitas dan Inovasi Siswa di Era Digital. *Indonesian Research Journal on Education*, *4*(2), 550–558. https://doi.org/10.31004/irje.v4i2.677

Mashami, R. A., & Khaeruman, K. (2020). Pengembangan Multimedia Interaktif Kimia Berbasis PBL (Problem Based Learning) untuk Meningkatkan Keterampilan Generik Sains Siswa. *Hydrogen: Jurnal Kependidikan Kimia*, *8*(2), 85. https://doi.org/10.33394/hjkk.v8i2.3138

Mufida, L., Subandowo, M. S., & Gunawan, W. (2022a). Pengembangan E-Modul Kimia pada Materi Struktur Atom untuk Meningkatkan Hasil Belajar. *JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika)*, *7*(1), 138–146. https://doi.org/10.29100/jipi.v7i1.2498

Mufida, L., Subandowo, M. S., & Gunawan, W. (2022b). Pengembangan E-Modul Kimia pada Materi Struktur Atom untuk Meningkatkan Hasil Belajar. *JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika)*, *7*(1), 138–146. https://doi.org/10.29100/jipi.v7i1.2498

Napitupulu, F. D., Sihombing, Y., Hutapea, D., M., Friska, & W., & Tambunan, J. J. V. (2024). Penggunaan Media Canva Dalam Pengenalan Power Point Dalam Proses Belajar Mengajar Di SMA Negeri 1 Kutalimbaru. *Kegiatan Positif : Jurnal Hasil Karya Pengabdian Masyarakat*, *2*(1), 86–96. https://doi.org/10.61132/kegiatanpositif.v2i1.819

Nofriyanti, D., & Hardeli, H. (2023). Analisis Kebutuhan LKPD Berbasis *Problem Based Learning* pada Materi Struktur Atom untuk Kelas X Fase E SMA. *YASIN*, *3*(5), 1251–1261. https://doi.org/10.58578/yasin.v3i5.1982

Novia, N. A., Radya Nasyawa, Susilo Tri Widodo, & Junianto. (2023). Penerapan *Problem Based Learning* Guna Meningkatkan Kecakapan Berpikir Kritis Bagi Siswa dalam Pembelajaran PKn SD. *Jurnal Basicedu*, *7*(6), 3923–3930. https://doi.org/10.31004/basicedu.v7i6.6428

Pradana, F. A. P., & Mawardi, M. (2021). Pengembangan Instrumen Penilaian Sikap Disiplin Menggunakan Skala Likert dalam Pembelajaran Tematik Kelas IV SD. *FONDATIA*, *5*(1), 13–29. https://doi.org/10.36088/fondatia.v5i1.1090

Rasya, G., Raksun, A., & Budiman, M. A. (2024). Penerapan Model Pembelajaran Berbasis Masalah (Problem Based Learning) untuk Meningkatkan Keaktifan Siswa dalam Belajar di Kelas III SDN 45 AMPENAN. *Jurnal Ilmiah Profesi Pendidikan*, *9*(3), 2230–2234. https://doi.org/10.29303/jipp.v9i3.2692

Resti, N., Ridwan, R., Palupy, R. T., & Riandi, R. (2024). Inovasi Media Pembelajaran Menggunakan AR (Augmented Reality) pada Materi Sistem Pencernaan: (Learning Media Innovation Using Augmented Reality on Digestive System Material). *BIODIK*, *10*(2), 238–248. https://doi.org/10.22437/biodik.v10i2.34022

Robiah, H., Ermiana, I., & Amrullah, L. W. Z. (2024). Pengembangan LKPD IPA Berbasis Problem Based Learning pada Materi Suhu dan Kalor untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Kelas V SDN 43

Ampenan. *Journal of Education*, *5*(4). https://doi.org/10.29303/goescienceed.v5i4.457

Rohmatulloh, R., Nindiasari, H., & Fatah, A. (2023). Pengembangan E-Modul Interaktif Berbasis *Problem-Based Learning* (PBL) untuk Meningkatkan Kemampuan Berpikir Kritis Matematis. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(4), 3599. https://doi.org/10.24127/ajpm.v12i4.8172

Rokhim, D. A., Widarti, H. R., & Fajaroh, F. (2020). Pengembangan Bahan Belajar Flipbook pada Materi Redoks dan Elektrokimia Berbasis Pendekatan STEM-PjBL Berbantuan Video Pembelajaran. *Kwangsan: Jurnal Teknologi Pendidikan*, *8*(2), 234. https://doi.org/10.31800/jtp.kw.v8n2.p234--250

Sahaat, Z., Nasri, N. M., & Abu Bakar, A. Y. (2020). ADDIE Model In Teaching Module Design Process Using Modular Method: Applied Topics in Design And Technology Subjects. *Proceedings of the 1st Progress in Social Science, Humanities and Education Research Symposium (PSSHERS 2019)*. 1st Progress in Social Science, Humanities and Education Research Symposium (PSSHERS 2019), Padang, Indonesia. https://doi.org/10.2991/assehr.k.200824.161

Sari, H., Al Idrus, S. W., & Rahmawati, R. (2022). Pengembangan Modul Pembelajaran Kimia Berbasis Model *Problem Based Learning* (PBL) pada Materi Koloid. *Chemistry Education Practice*, *5*(1), 99–106. https://doi.org/10.29303/cep.v5i1.2697

Sodik, A. J., Santoso, G., & Winata, W. (2023). Mengembangkan Kemampuan Berpikir Kritis dan Komunikasi Efektif untuk Kesepakatan Bersama di Kelas 4. *02*(04), 395–420. https://doi.org/10.9000/jpt.v2i4.647

Sucipta, I. W., Candiasa, I. M., & Sudirtha, I. G. (2023). Pengaruh Model Pembelajaran Berbasis Masalah dan Bentuk Asesmen Formatif terhadap Kemampuan Berpikir Kritis. *13*(2), 168-178. https://doi.org/10.23887/jpepi.v13i2.2660

Sugianto, S. (2024). Pengembangan Perangkat Pembelajaran *Problem Posing* untuk Meningkatkan Kemampuan Berpikir Kritis Matematis dan *Self-Efficacy* Siswa Kelas VIII SMP Swasta Ali Imron. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *8*(2), 1794–1813. https://doi.org/10.31004/cendekia.v8i2.3407

Sugiarti, M. I., & Dwikoranto, D. (2021). Peningkatan Kemampuan Berpikir Kritis Peserta Didik Melalui Pembelajaran *Blended Inquiry Learning* Berbantuan *Schoology* pada Pembelajaran Fisika. *Quantum: Jurnal Inovasi Pendidikan Sains*, *12*(1), 49. https://doi.org/10.20527/quantum.v12i1.10262

Susanto, A., Qurrotaini, L., & Mulyandini, N. (2020). Peningkatan Kemampuan Berpikir Kritis Siswa pada Mata Pelajaran IPS melalui Model *Controversial Issue*. *Jurnal Holistika*, *4*(2), 71. https://doi.org/10.24853/holistika.4.2.71-76

Suswati, U. (2021). Penerapan *Problem-Based Learning* (PBL) Meningkatkan Hasil Belajar Kimia. *TEACHING : Jurnal Inovasi Keguruan dan Ilmu Pendidikan*, *1*(3), 127–136. https://doi.org/10.51878/teaching.v1i3.444

Waruwu, M. (2024). Metode Penelitian dan Pengembangan (R&D): Konsep, Jenis, Tahapan dan Kelebihan. *Jurnal Ilmiah Profesi Pendidikan*, *9*(2), 1220–1230. https://doi.org/10.29303/jipp.v9i2.2141