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

December 2025. 13(6)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 1200-1215

Development of Teaching E-Modules on Atomic Structure Material Based on the Merdeka Curriculum

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Article History
Received: 19-11-2025
Revised: 19-12-2025
Published: 31-12-2025

Keywords: E-Module learning; atomic structure; merdeka curriculum

Abstract
The purpose of this study was to develop and test the feasibility of materials and media, as well as to observe teachers' responses to e-learning modules on atomic structure based on the independent curriculum. This study uses the Research and Development method with the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. However, the development process is limited to the development stage with the aim of producing e-learning modules that are theoretically feasible based on expert assessment and user response, without empirically testing the effectiveness of the product. The module that has been developed is tested for feasibility by each of the 2 media experts and material experts to determine whether the module is suitable for use. In addition to the feasibility assessment, a response test to the product was also carried out involving 2 teachers from driving schools in Pontianak city. The results of the analysis in the material test were 88%, the media test was 84%, and the teacher response questionnaire to the teaching module was 96%. So it can be concluded that the teaching e-module on atomic structure material based on the independent curriculum developed is feasible to use as a learning tool because it has passed the feasibility assessment by material and media experts and received a very good response from chemistry learning teachers because it has passed the response test. The uniqueness of this research lies in the development of an e-learning module that systematically maps Learning Outcomes (CP) into Learning Objectives (TP) and Learning Objective Sequences (ATP), and is designed in an interactive digital format to overcome teachers' difficulties in planning lessons under the Merdeka Curriculum. Researchers suggest continuing this research at the next stage, namely implementation and evaluation to see the effectiveness of the teaching modules produced because the teaching modules can also be used by teachers in learning chemistry so as to make it easier for teachers to have teaching module references that are more flexible and can be accessed at any time.

How to Cite: Melviani, Enawaty, E., & Masriani. (2025). Development of Teaching E-Modules on Atomic Structure Material Based on the Merdeka Curriculum. Hydrogen: Jurnal Kependidikan Kimia, 13(6), 1200–1215. https://doi.org/10.33394/hjkk.v13i6.18750

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INTRODUCTION

The independent curriculum is a learning design that provides opportunities for students to learn calmly, relaxed, fun, stress-free and free from pressure, in order to show their natural talents. With the independent curriculum policy, it is a rearrangement in the national education system in Indonesia. The independent curriculum is expected to make students develop according to their potential and abilities because with an independent curriculum students get critical, quality, expressive, applicable, varied and progressive learning. "This new curriculum change requires cooperation, strong commitment, seriousness and real implementation from all parties, so that the profile of Pancasila students can be embedded in students" (Fetra and Risda, 2020). The independent learning curriculum has four principles that are transformed into new

policy directions, one of which is the lesson plan. The independent curriculum provides flexibility for teachers to freely choose, create, use, and develop lesson plan formats (Deni, et al, 2022). The lesson plans in the previous curriculum were known as teaching modules in the independent curriculum (Susanti, 2021).

Teaching modules are learning tools developed based on the applicable curriculum with the aim of achieving the established competency standards (Nurdyansyah, 2018). Teaching modules play an important role in helping teachers design systematic and focused learning (Nesri & Kristanto, 2020). In developing learning tools, teachers play a central role because they are required to have pedagogical and innovative skills so that the teaching modules developed are in line with the characteristics of the students and the demands of the curriculum. However, in practice, many teachers still experience difficulties in compiling and developing teaching modules, especially in the implementation of the Merdeka Curriculum, which requires flexibility, mapping of Learning Outcomes (CP) to Learning Objectives (TP), and the independent preparation of Learning Objective Flows (ATP). This condition causes the learning process to tend to be less planned and unsystematic, thereby potentially reducing the quality of learning interactions between teachers and students (Merta, 2022). Therefore, the development of e-teaching modules that are adaptive to the Merdeka Curriculum is a solution to overcome the practical difficulties teachers face in designing learning. E-modules that are structured and easily accessible are expected to facilitate teachers in the process of planning and implementing learning, save time in preparing lessons, and increase the effectiveness and appeal of learning in the classroom.

In addition, the challenges faced by teachers in implementing the Merdeka Curriculum are becoming increasingly complex, particularly in understanding changes in the learning structure. A number of studies show that teachers still have difficulty translating Learning Outcomes (CP) into Learning Objectives (TP) and developing a systematic Learning Objective Flow (ATP) due to limited conceptual understanding and a lack of technical training (Nadlir et al., 2023; Rahmawati & Sudrajat, 2023). Research at SMP Negeri 5 Pinrang also revealed that limited teaching materials exacerbate teachers' difficulties in developing learning tools that meet the requirements of the Merdeka Curriculum, so that teachers tend to need practical and ready-to-use teaching tools (Rahmawati et al., 2023). In addition, high administrative burdens and time constraints are major obstacles to the development of effective and contextual teaching modules (Sari et al., 2024). These conditions emphasize the importance of providing learning tools that are easy to understand, applicable, and ready to use to support the optimal implementation of the Merdeka Curriculum (Putri et al., 2023).

Based on the results of interviews with teachers who teach in schools driving the independent curriculum, information was obtained that the time used to make modules was very little when compared to the ongoing learning process. In addition, teachers have not been able to reduce CP (learning outcomes) to TP (learning objectives) and have not been able to reduce TP to the preparation of ATP (flow of learning objectives). Based on these problems, it is necessary to develop additional teaching modules that are flexible and can be accessed easily using cellphones, tablets or laptops. One of the media that can be used is google sites which is a platform from google that can be designed in such a way as to become a more attractive appearance by including files of learning materials, animated videos, and games that support the learning process by utilizing various existing features. This is in line with the opinion of Divayana, Suyasa & Sugihartini (2016) who say that google sites are very easy to use, especially to support learning by maximizing features such as google docs, sheets, forms. calender, awesome table and so on. The completeness of the features available on google sites can also make it easier for teachers to simultaneously make google sites a learning evaluation tool using the google form feature.

Based on the above description, an e-learning module was developed on atomic structure based on the independent curriculum to determine the feasibility and response to the e-module. The uniqueness of this research lies in the development of e-modules that systematically map Learning Outcomes (CP) into Learning Objectives (TP) and Learning Objective Flow (ATP), and are designed in an interactive digital form that is easily accessible through various devices, so that it not only supports student independence in learning, but also helps teachers in overcoming difficulties in planning learning in accordance with the characteristics of the Merdeka Curriculum.

METHOD

The research method used in the development of this Merdeka Curriculum-based e-module on atomic structure is research and development using the ADDIE model according to Branch (2009), which includes the stages of analysis, design, development, implementation, and evaluation. In this study, the development process was only carried out up to the development stage. This limitation was imposed because the main focus of the study was to produce a theoretically feasible e-module product based on expert assessment and user response, so that the study was not continued to the implementation and evaluation stages, which aim to test the effectiveness of the product empirically (Branch, 2009; Sugiyono, 2019). Nevertheless, the use of the ADDIE model still provides a systematic and comprehensive framework for the learning tool development process.

During the analysis stage, teachers' understanding of the Merdeka Curriculum, atomic structure material, learning objectives, learning processes, learning resources used, obstacles encountered during curriculum implementation, learning methods and media, and teachers' expectations for the development of teaching e-modules were identified. Information gathering in this analysis stage was conducted through interviews, which aimed to obtain in-depth data related to the real needs and problems faced by teachers in learning (Creswell, 2014).

The results of the analysis in the first stage were used as the basis for developing a Google Sites-based e-module design in the design stage. The design was compiled in the form of a storyboard containing the components of Learning Outcomes, Learning Objectives, initial competencies, sparking questions, learning models, learning activities, student worksheets, and assessments. The storyboard was developed to provide a systematic overview of the material presentation flow and e-module display before it was realized into a tangible product (Branch, 2009; Munir, 2017).

The development stage is the realization of the design that has been made previously. At this stage, the e-learning module is developed in accordance with the storyboard that has been prepared. The product display design is created using Adobe Photoshop and Canva software to produce an attractive and communicative visual display. All learning support materials that have been collected at the design stage are then compiled into a complete e-learning module in accordance with the Merdeka Curriculum learning concept (Arsyad, 2020).

The developed e-learning modules were then tested for feasibility by two subject matter experts and two media experts to assess the suitability of the content, language, presentation, and media display. In addition, a teacher response test was conducted involving two teachers from pilot schools in Pontianak City to determine user responses to the developed e-modules. These feasibility and response tests aim to ensure that the developed product is suitable for use as a learning tool (Sugiyono, 2019).

The data collection techniques used in this study consisted of direct communication and indirect communication. Direct communication was conducted through interviews, while

indirect communication was conducted using response test questionnaires. The questionnaires used were closed-ended questionnaires, in which respondents were asked to choose from the answers provided, and were supplemented with a comments column to obtain qualitative input (Riduwan, 2018).

The data collection tools used included interview guidelines, teacher response questionnaires, and e-module teaching feasibility assessment sheets. The data analysis techniques used consisted of qualitative and quantitative data analysis. Qualitative data analysis was carried out by analyzing the criticism and suggestions provided by subject matter experts, media experts, and teachers. Meanwhile, quantitative data analysis was conducted by analyzing the scores obtained from the feasibility assessment sheets and teacher response questionnaires using the Likert scale (Likert, 1932). The scores obtained were then interpreted to determine the level of feasibility and response to the developed e-teaching modules.

To ensure the validity of the data obtained, the research instruments used were first tested for validity and reliability before being used in data collection. The validity of the instruments was determined through expert judgment, namely by requesting assessments from subject matter experts and media experts on the suitability of each item in the instrument with the indicators being measured, including aspects of content, language, presentation, and media display. Validation by experts aims to ensure that the instruments accurately represent the constructs being measured and are relevant to the objectives of developing e-learning modules (Arikunto, 2018; Sugiyono, 2019; DeVellis, 2017).

In addition, the teacher response questionnaire instrument also underwent limited testing with respondents who had characteristics similar to the research subjects to assess the clarity of the wording, readability, and potential for multiple interpretations of each statement. Feedback from the pilot test was used as a basis for refining the instrument before it was used more widely (Riduwan, 2018; Creswell & Creswell, 2018).

The reliability of the instrument was assessed based on the internal consistency of the items in the teacher response questionnaire. The instrument was deemed reliable if it showed a high level of consistency in measuring the same aspect. Conceptually, this reliability measurement refers to the principle of developing the Likert scale as a tool for measuring respondents' attitudes and perceptions, which emphasizes consistency and stability of measurement results (Likert, 1932; Tavakol & Dennick, 2011). With the fulfillment of validity and reliability aspects, the research instrument is considered suitable for use in obtaining accurate and reliable data.

The answer choices and scores used in the assessment of material experts and media experts are:

Table 1. Score guidelines

Assessment	Description	Score
SA	Strongly agree	5
A	Agree	4
LA	Less agree	3
D	Disagree	2
SD	Strongly disagree	1

(Source: Sugiyono, 2016)

The assessment criteria in determining the feasibility of media and materials are expressed in percentages calculated using the following formula:

$$xi = \frac{\sum s}{\text{Smax}}\ x100$$

Description:
Xi : Feasibility value of each aspect
ΣS : Total score
Smax : Maximum score

The percentage score results obtained from the calculation are interpreted in the following table criteria:

Table 2. Guidelines for eligibility categories

No.	Percentage	Category
1.	80-100	Very feasible
2.	66-79	Worth
3.	56-65	Decent enough
4.	46-55	Less feasible
5.	0-45	Very less feasible

Source: (Arikunto and Jabar, 2018)

Furthermore, the scores in the teacher response questionnaire will be analyzed using a Likert scale as follows:

Table 3. Response questionnaire score guidelines

	Assessment	Description	Score
Positive statement	SA	Strongly agree	5
	A	Agree	4
	N	Neutral	3
	D	Disagree	2
	SD	Strongly disagree	1
Negative statement	SA	Strongly agree	1
	A	Agree	2
	N	Neutral	3
	D	Disagree	4
	SD	Strongly disagree	5

Based on the results of the above score analysis to calculate the interpretation of the score of each statement item using the following equation:

$$Interval = \frac{\text{Score of question/statement items}}{\text{Highest score of question/statement items}}\ x\ 100$$

The score results obtained from the teacher response questionnaire will be interpreted in the criteria in the following table:

Table 4. Criteria for interpretation of response questionnaire scores

Percentage Score (%)	Score Category
81 – 100	Very good
61 – 80	Good
41 – 60	Fairly Good
21 – 40	Not Good
0 – 20	Very Poor

Source: (Kartini, et al 2020)

RESULTS AND DISCUSSION

The teaching module developed is an independent curriculum-based teaching e-module on atomic structure material by implementing differentiated learning for students. Differentiated

learning is a series of actions chosen wisely by the teacher to structure learning experiences that suit the individual needs of each student, taking into account general intelligence, and focus on student learning development (Fitra, 2022). Differentiated learning in the teaching module is differentiated learning in content, process and product. Differentiated learning on content by providing teaching materials presented in the form of modules. While differentiated learning in the process by classifying groups by taking into account the ability of students (using peer tutors) and providing problems that will be solved by students with a predetermined time limit. The development of this teaching module aims to design learning tools that can be tailored to the needs of teachers and students and in line with differentiated learning based on the principles of the independent curriculum. Effective learning tools must have a high level of validity so that they are worth testing (Nurhayati, 2017).

The process of developing teaching e-modules was carried out with the analysis stage carried out by interviewing the chemistry teacher of SMA Negeri 1 Pontianak. The results of the interview found that the curriculum used was the independent curriculum and the school had also entered into a driving school. SMA Negeri 1 Pontianak uses the independent curriculum in phase E (class X) and F (class XI) and teaching modules as learning tools. The results of the interview also obtained information that teachers experienced obstacles in preparing teaching modules due to differences in teaching modules and lesson plans. Teaching modules have more complete components than lesson plans. In the teaching module there are several components that are not in the lesson plan such as the components of the Pancasila learner profile, initial competence, meaningful understanding, triggering questions and diagnostic assessment to determine the characteristics and needs of students. In addition, it is also difficult for teachers to get references and access teaching modules that are used as examples. Teachers need an independent curriculum teaching module based on differentiated learning that is easily accessible to teachers and can accommodate the needs of teachers and learners. Learner learning will reach an optimal level if it is designed using a differentiation approach, because this strategy has the capacity to meet the various needs of each learner (Kristiani et al., 2021).

Next is the design stage or the teaching module design stage. There are several things that are done, starting from determining the application for teaching module design, collecting teaching module component references, designing teaching modules, finding teaching module content references, making teaching module designs, and preparing teacher response tests. At this stage, the teaching module was designed using the Canva application which was then entered into google sites. The teaching module consists of 3 components, namely general information, core components and attachments. General information includes elements such as module identity, initial competencies, Pancasila learner profile, target learners and learning model. Meanwhile, the core component includes learning objectives, assessment, meaningful understanding, triggering questions, learning activities, and learner and educator reflections. The appendix consists of Problem Based Learning (PBL)-based learner worksheets (LKPD), learner and educator reading materials, and a bibliography.

Furthermore, the teaching modules that have been developed at the design stage are given a feasibility assessment by experts. This stage is carried out to determine the level of feasibility of teaching modules on atomic structure material based on the independent curriculum in terms of content/material and media aspects. The content/material aspect contains an assessment of the components in the module. This aspect was assessed by 2 validators. A number of experienced experts or experts conduct product validation to evaluate the advantages and disadvantages of the products produced. The purpose of this step is so that the product can be used as intended (Sugiyono, 2014). The teaching module validation sheet adapts the assessment sheet in the MBKM guide. The LKPD section in the teaching module assessment is given a separate assessment, namely the assessment by the media expert. The score of each aspect can be seen in table 5.

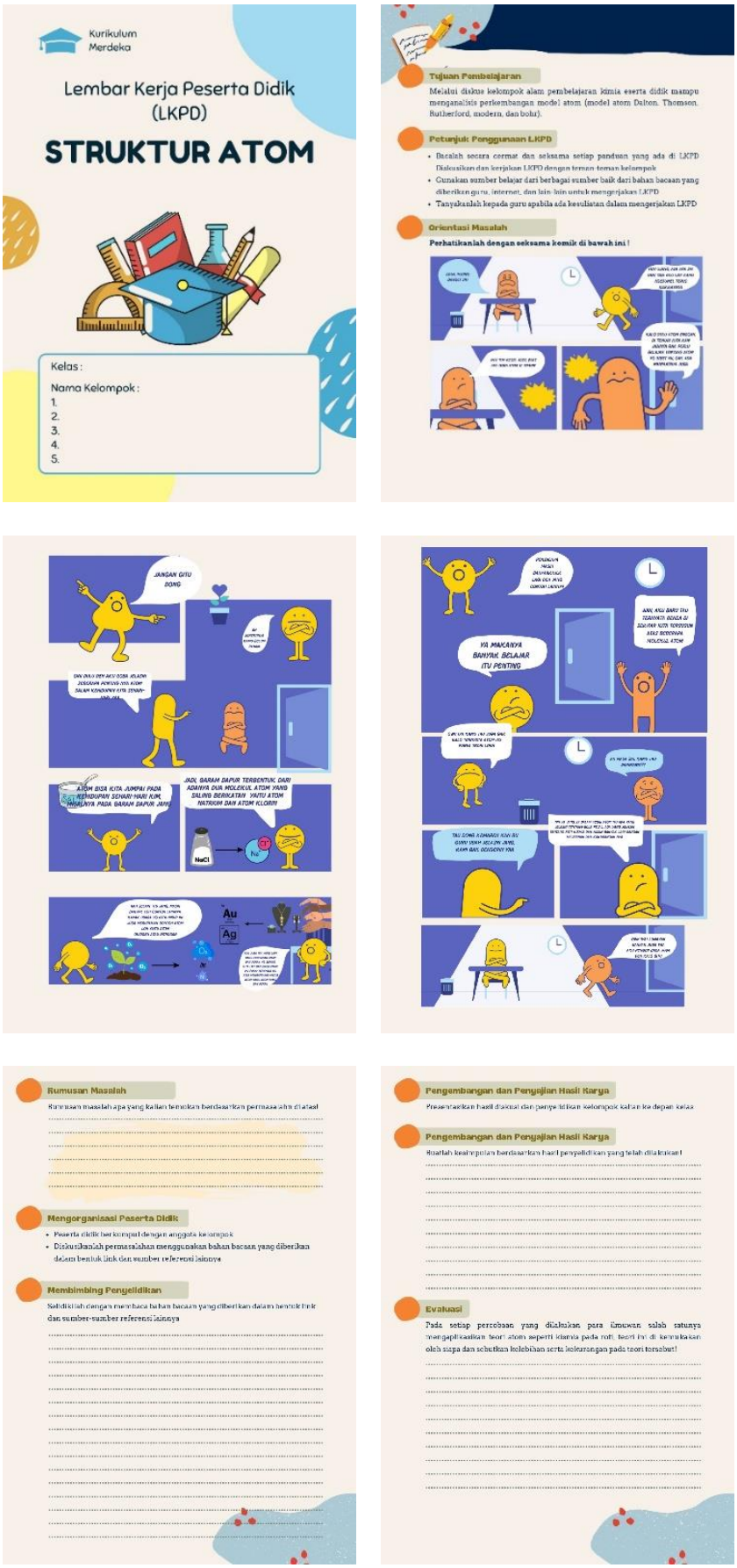


Figure 1. Students Worksheet (LKPD)

The results in table 5 show that the average percentage score on the material aspect is 88%, which based on (Arikunto and Jabar, 2018) includes a very feasible category because it is in the range of 80-100%. Although on average it is in the very feasible category, each aspect requires improvement.

Table 5. Material expert validation results

NO.	Assessment aspect	Average	Persentase skor (%)
1.	Teaching module identity	3	75
2.	Initial competency	3	75
3.	Suitability of objectives with CP indicators	3,85	96
4.	Learning objectives and indicators are adaptive and future-oriented (science and technology).	3	75
5.	Pancasila student profile	3,5	88
6.	Facilities and infrastructure	4	100
7.	Target learners	3,5	88
8.	Determination of learning models/strategies and learning resources	3	75
9.	Assessment	3,35	88
10.	Learner development	3,5	88
11.	Assessment instrument design	3,5	88
12.	Meaningful understanding	4	100
13.	Sparking question	4	100
14.	Learning activities	3,35	88
15.	Reflection	4	100
16.	Teaching materials	3,5	88
17.	Bibliography	3,5	88
Total percentage (%)			**88**

Based on all aspects of the assessment, it can be seen that the aspects of the teaching module identity, initial competencies, learning objectives and indicators are adaptive and future-oriented, as well as the determination of learning models/strategies and learning resources only get a percentage of 75% or fall into the feasible category. This shows that in this category there are still shortcomings to be said to be very feasible, therefore it needs to be improved to enter the very feasible category. However, with the limitations of the author, this research is sufficient to reach the feasible category. Aspects that get perfect scores or 100% are aspects of facilities and infrastructure, meaningful understanding, triggering questions, and reflection.

Facilities and infrastructure aspects obtain perfect score because the teaching module has supported facilities and infrastructure during teaching and learning activities, therefore it is said to be very feasible or perfect. The aspect of meaningful understanding is said to be perfect because in meaningful understanding students are considered capable of understanding the language and vocabulary and sentences contained in meaningful understanding. The reflection aspect is said to be perfect because the reflection includes elements of (1) content knowledge (2) pedagogical knowledge, and (3) content packaging knowledge in meaningful learning (Abdurrahman, 2013) for teachers, while for students the reflection aspect is easy to understand and access.

Aspects that reach perfection and fall into the category of very feasible but not perfect are aspects of the suitability of objectives with CP indicators that get a score of 96%, this is already said to be perfect because it is close to perfect. In this assessment there is no need for further review. In the aspect of assessing the profile of Pancasila students, learner targets, assessment, learner development, design of assessment instruments, learning activities, teaching materials,

and bibliography obtained a score of 88% which based on (Arikunto and Jabar, 2018) falls into the category of very feasible. So it can be concluded that this aspect can be used in the learning process and can be understood by students and educators.

The media aspect in this study includes an assessment of the Student Worksheets (LKPD) contained in the teaching module. This aspect was assessed by two media expert validators using a Likert scale-based assessment instrument. The use of the Likert scale aims to measure the level of product feasibility quantitatively based on the perceptions of experts (Likert, 1932; Riduwan, 2018). The assessment results obtained were then analyzed in the form of percentages, as presented in Table 6. Based on these measurements, an average percentage value of 84% was obtained. This measurement was carried out to ensure that the developed product met the feasibility criteria as a learning medium (Sugiyono, 2019). Referring to the feasibility criteria according to Arikunto and Jabar (2018), a percentage of 84% is included in the very feasible category because it is in the range of 80–100%. Thus, it can be concluded that the LKPD media in the developed teaching module is feasible for use in the highly feasible category. However, the assessment results for each aspect still show some areas for improvement, so product refinement is still needed to improve the overall quality of the teaching module.

Table 6. Media expert validation results

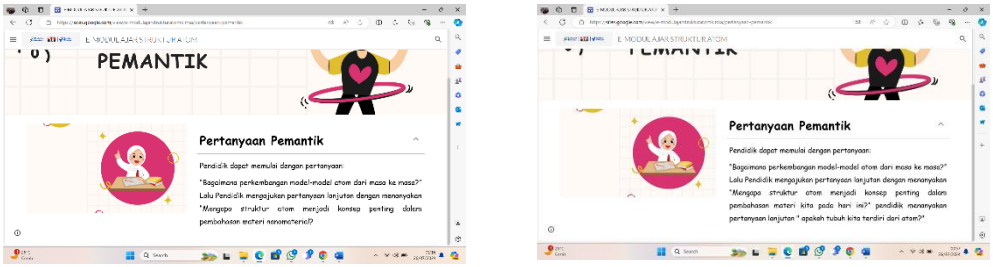
NO.	Assessment aspect	Average Score	Percentage score (%)
1.	Presentation of LKPD	3,5	88
2.	Suitability of LKPD with Problem Based Learning model steps	3,5	88
3.	Suitability of LKPD questions with learning objectives	3	75
Total percentage score (%)			84

When viewed from various aspects of the assessment on the assessment by media experts, it can be seen in table 6 that in the aspect of the presentation of the LKPD and the aspect of the suitability of the LKPD with the steps of the Problem Based Learning model get a percentage of 88% which based on (Arikunto and Jabar, 2018) falls into the category of very feasible to use so there is no need to go through the revision and improvement stage because the presentation and steps in the LKPD are very suitable for PBL learning. In the aspect of the suitability of LKPD questions with learning objectives, the percentage score is 75%, which if based on (Arikunto and Jabar, 2018), it falls into the Decent category, not very feasible or perfect. Given the limitations, the researcher suffices the assessment to the feasible category.

Based on the results of the analysis and also the assessment of media experts and material experts, it can be concluded that this teaching module can be used to enter the response test stage. In the feasibility assessment process there are several suggestions or improvements from material and media validators, among others:

On the triggering questions page, the validator gave suggestions that the triggering questions used were easier for students to understand. So there was a change that originally the triggering question was "Educators can start with the question: "How has the development of atomic models over time?" Then the Educator asked a follow-up question by asking "Why is atomic structure an important concept in the discussion of nanomaterials?" then after being revised it changed to Educators can start with the question: ""How have atomic models evolved over time?"" Then the Educator asks a follow-up question by asking "Why is atomic structure an important concept in the discussion of our material today?" the educator asks a follow-up

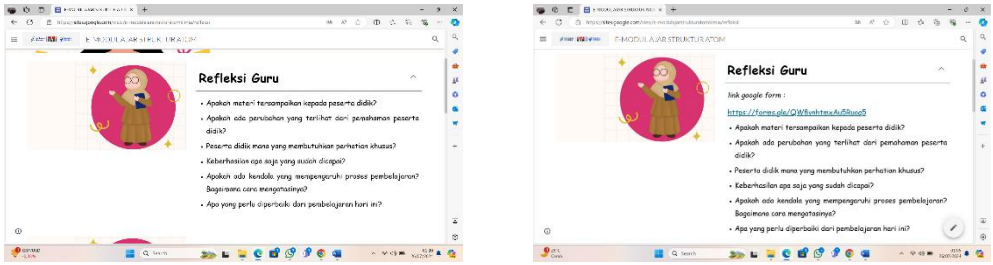
question "is our body made up of atoms?"". This change is considered by the validator to be more effective to support students' understanding of the questions asked.



(a) (b)

Figure 2. Trigger question display (a) before revision (b) after revision

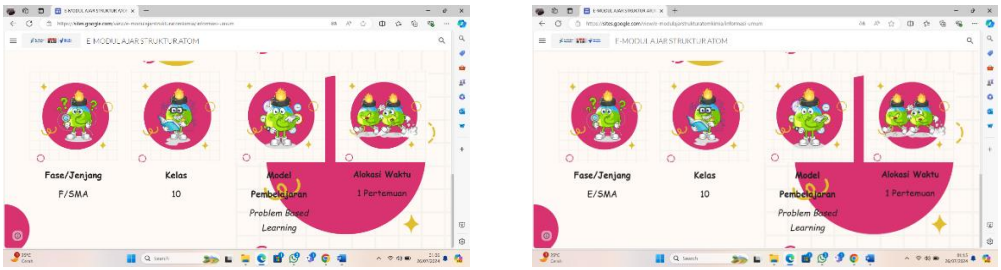
On the reflection page, the validator suggests that the teacher's reflection also uses a google form because in the results before the revision it can be seen in Figure 4 that there is no google form on the reflection page. The placement of this google form link aims to make it easier for teachers to evaluate their own learning outcomes. This statement is in accordance with the statement from (Hamdan and Dessy, 2016) which states that the use of google forms as teacher evaluation materials in learning devices is considered more effective and easily accessible at any time rather than using paper sheets.



(a) (b)

Figure 3. Teacher reflection display (a) before revision (b) after revision

On the general information page, there was an error in the phase section, so the validator suggested correcting it, namely from phase E to phase F.



(a) (b)

Figure 4. Phase display (a) before revision (b) after revision

In the LKPD section as shown in Figure 6 in part (a) is not in accordance with the problem-based learning model, therefore the Validator suggests making LKPDs that are in accordance with the problem-based learning model consisting of the learning objectives section, instructions for using LKPD, problem orientation, problem formulation, organizing students, guiding investigations, developing and presenting work, and the last part of the evaluation. The results of the revision can be seen in Figure 6 part (b).

After the learning media is declared feasible based on the results of the expert assessment and has undergone improvements, the next step is testing (Shafira & Wiranda, 2022). This research trial involved a teacher response test conducted on 2 independent curriculum driving school chemistry teachers from SMAN 8 Pontianak and SMA Al-Mumtaz through an assessment of

the teacher response questionnaire. This response test was conducted to find out the teacher's reactions, responses and comments on the teaching module developed.

The following are the results of the teacher response test which consists of aspects, visual *communication, software engineering, material, and learning which can be seen in Table 7.*

Table 7. Teachers' responses to teaching modules

Aspects	No.	Indicator	Percentage (%)
Visual communication	1.	Presentation of teaching modules	80
	2.	Use of font size	90
	3.	Visual presentation of teaching modules	100
Software engineering	4.	Ease of media use	100
	5.	Media flexibility	100
Material	6.	The effect of teaching modules on student learning interest	90
	7.	Systematics of teaching modules	100
	8.	Ease of use Language	90
	9.	Clarity of sentences used	100
Learning	10.	Trigger question	100
	11.	Suitability of the learning process with learning outcomes	100
Total percentage			**96**

When viewed from various assessment aspects in the assessment by media experts, Table 6 shows that the aspects of LKPD presentation and the suitability of LKPD with the Problem-Based Learning model steps received a percentage of 88%, which, based on (Arikunto and Jabar, 2018) This falls into the category of highly suitable for use, so there is no need to go through the revision and improvement stage because the presentation and steps in the LKPD are already very suitable for PBL learning. In terms of the suitability of the LKPD questions with the learning objectives, a score of 75% was obtained, which, based on (Arikunto and Jabar, 2018), falls into the category of suitable, not very suitable or perfect. Given the limitations, the researcher considered this assessment sufficient for the suitable category.

In the software engineering aspect, there are 2 items of statement, after data processing, the average percentage of all questions is 100% in the very good category, which means that the ease of use of the media and the flexibility of the media are considered very good based on the results of the teacher's response. This is very much needed because as a teacher, the selection of learning media that is easy to access anytime and anywhere is needed to achieve the learning objectives that have been set (Teni, 2018).

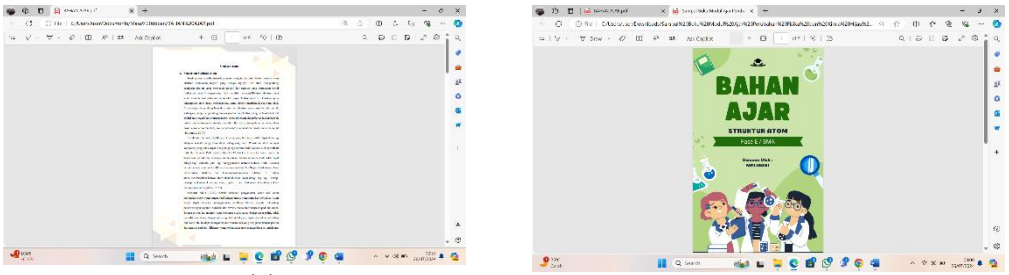
In the aspect of material, there are 4 items of statement, after data processing, the average percentage on all questions is 95% with a very good category which means that the material in the teaching module can have an influence on student interest in learning, this is needed because based on information from (Teni, 2018) that good learning media can be a learning resource that can help teachers to enrich students' insights. In addition to indicators of student understanding, other indicators are also seen, namely the systematics of the module, the use of language, and the clarity of the sentences used, this shows that the teaching module is systematic, then the sentences and language use are appropriate and easy to understand.

In the learning aspect, there are 2 items of statement, after data processing, the average percentage on all questions is 100% with a very good category, which means that the triggering questions and the learning process are very much in accordance with the learning outcomes.

The scores obtained from 4 aspects of the teacher response test were then averaged and obtained an average teacher response test score of 96% which based on (Kartini, et al 2020) fell into the very good category. Teachers also agree that the teaching module can be used as a teaching tool because the teaching module that has been developed adopts differentiated learning. Teaching modules that have been made by teachers are teaching modules that have not adopted differentiated learning. The learning model used is also different from what teachers usually use. The learning model used by the teacher is a discovery learning model and the teaching module that has been developed uses a problem-based learning model. Therefore, the teacher's response to the teaching module that has been developed is very good.

Based on qualitative feedback from teachers obtained through response questionnaires and interviews, the developed e-learning modules are considered capable of helping teachers organize learning more systematically, particularly in developing learning pathways that are aligned with the Learning Outcomes, Learning Objectives, and assessments in the Merdeka Curriculum. Teachers stated that the structured presentation of material in a single digital platform facilitated lesson preparation and saved time, as well as reducing dependence on separate teaching materials. In addition, the visual display, student worksheets, and stimulating questions in the e-module were considered capable of increasing student engagement and activity during the learning process, as well as supporting independent learning and differentiation in accordance with the characteristics of the Merdeka Curriculum.

There are suggestions or input from teachers on the teaching modules developed. On the teaching material page, the teacher suggested making the teaching material more interesting with good visuals so that it would attract students to read the teaching material.



(a) (b)

Figure 5. Appearance of teaching materials (a) before revision (b) after revision

The developed teaching module was declared suitable for use because it had undergone a validity test by subject matter experts and media experts, as well as a response test by lecturers and teachers of chemistry. The validity test results showed a very high category, while the user response test obtained a percentage in the very suitable category, so that the teaching module met the criteria as a learning tool that was ready for use. These findings are in line with Sugiyono's (2019) opinion, which states that the feasibility of research and development products can be determined through expert validation and user response. Other studies also show that teaching modules validated by subject matter and media experts have better content and appearance quality and have the potential to increase learning effectiveness (Arikunto & Jabar, 2018). In addition, international research by Plomp and Nieveen (2013) confirms that validity and practicality are key indicators in assessing the quality of educational development products before they are widely implemented. Thus, the results of this study reinforce that the teaching modules developed are feasible for further development and use in chemistry learning in accordance with the requirements of the Merdeka Curriculum.

In addition, when the results of this study are compared with previous studies or with the teaching material assessment standards set by the Ministry of Education, Culture, Research, and Technology, these findings show strong consistency. For example, several studies on the

development of teaching modules based on independent curriculum and differentiated learning (such as research by Kristiani et al., 2021 and Nurhayati, 2017) report that a validity score range of 80–100% is considered very feasible and sufficient to proceed with the product to the limited implementation or field trial stage. Thus, the feasibility percentage of 84–96% obtained in this study is in line with the results of those studies.

Qualitative feedback from teachers indicates that limitations in technical training related to the Merdeka Curriculum and the lack of time to manually develop learning modules are major obstacles in lesson planning. Teachers stated that the process of translating Learning Outcomes into Learning Objectives and Learning Objective Sequences takes a long time and is often not supported by adequate guidance. These findings are in line with previous studies which mention that the lack of continuous training and high administrative workload make it difficult for teachers to develop learning tools independently (Rahmawati & Sudrajat, 2023; Sari et al., 2024). The presence of digital-based teaching e-modules is considered capable of overcoming these problems because they provide a ready-to-use, organized learning structure that is in line with the Merdeka Curriculum, so that teachers do not need to compile modules from scratch. In addition, the flexible and accessible format of e-modules allows teachers to save time in preparing lessons and focus more on facilitating and engaging students, as reported in international studies on the effectiveness of digital learning modules in supporting teacher readiness (Koehler et al., 2014; Trust & Whalen, 2020).

On the other hand, certain aspects that received lower scores, such as module identity, initial competence, and the suitability of LKPD questions with learning objectives, have also been common findings in previous teaching module development studies. This shows that the areas for improvement that emerged in this study are not anomalies, but rather are in line with the challenges often found in the process of developing independent curriculum teaching modules. Thus, even though this study was terminated at the development stage due to time constraints and research focus, the results obtained are still within the feasibility standards according to previous studies.

CONCLUSION

Based on the research results, it can be concluded that the e-learning module on atomic structure based on the Merdeka Curriculum that was developed is very suitable for use as a learning tool. The validation results by subject matter experts and media experts showed percentages of 88% and 84%, respectively, while the results of the response test by chemistry teachers reached 96% with a very good category. The novelty of this research lies in the development of teaching e-modules that systematically map Learning Outcomes (CP) into Learning Objectives (TP) and Learning Objective Flow (ATP), and are designed in an interactive digital form to address teachers' difficulties in planning learning under the Merdeka Curriculum. The impact of this research is pedagogical and practical, namely providing ready-to-use, flexible, and easily accessible learning tools through various digital devices, thereby helping teachers save time in planning and supporting the implementation of the Merdeka Curriculum more effectively. In addition, academically, this research provides empirical contributions in the field of developing competency-based digital learning tools.

RECOMMENDATIONS

Based on the results of research and development obtained regarding e-learning modules on atomic structure material based on the independent curriculum, researchers suggest that as a follow-up, further research should continue the process to the implementation and evaluation

stages so that the effectiveness of using e-modules in improving students' conceptual understanding can be tested empirically. In addition, the development of teaching modules can be directed towards adding interactive features, integrating more varied formative assessments, and conducting trials in various school contexts so that the modules are more adaptive to diverse learning needs. Thus, these highly feasible modules have the potential to have a broader impact if implemented directly in classroom learning.

ACKNOWLEDGEMENTS

The researcher would like to thank the heads of SMA Negeri 1 Pontianak, SMA Negeri 8 Pontianak, SMA Al-Mumtaz, and the institution of Tanjungpura University who helped this research.

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