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# Development of e-modules of basic laws of chemistry based on problem-based learning to improve critical thinking skills

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ABSTRACT

Critical thinking is an important aspect of the skills expected in 21st-century learning, especially in chemistry learning. Based on preliminary studies that have been carried out, critical thinking skills are still not practiced in the learning process, and the teaching materials used are still only a few that relate daily life problems to the material. This study aimed to evaluate the validity, practicality, and effectiveness. The ADDIE model was used as the method of this research, 36 students of class X-E of Senior High School 5 Banjarmasin were the subjects of the development research. Data were collected with test and non-test instruments. Analysis of validity, practicality, and effectiveness were the analysis techniques used in this study. The findings of this study are that the e-module has a very high level of validity which is 94.93, very practical with a practicality score of 84.46, and effective with an N-Gain of 81.15. Suggestions for future researchers are that the developed e-modules can be accessed without using the internet and the testing of the developed products can be more than one school.



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## INTRODUCTION

Critical thinking is expected to be possessed by every learner as part of 21st-century learning competencies. According to Manik et al., (2020) and Prathiwi & Utami (2019), developing and acquiring critical thinking is important when studying chemistry. Learning should not be limited to mastering the material but also allow learners to develop the life skills they need. Critical thinking is the ability to reason, focusing on making decisions about truth and appropriate action.

The level of critical thinking in Indonesia is still low as shown by data from 2015, 2018, and 2022 that Indonesia is still below the average score of PISA completeness (Kurniawati, 2022; OECD, 2019; Sutrisna, 2021). The PISA results showed three weaknesses of Indonesian students in terms of: (1) applying ideas to real situations, (2) providing clear scientific explanations, and (3) understanding the evidence provided (Arini et al., 2021). PISA results reflect students' understanding of the curriculum and their ability to think critically, interpret information, and solve problems in various life contexts.

Data from preliminary studies conducted at Senior High School 5 Banjarmasin support the conclusion about the low level of critical thinking, namely (1) the critical thinking learning process

is less focused, (2) the teaching materials are still few that relate life problems relevant to the material. According to research by Amijaya et al., (2018) and Priyadi et al., (2018) teacher skills in implementing the learning process are an additional cause of low critical thinking skills, namely the teacher only focuses on delivering learning material so that the learning process tends to be teacher-centered resulting in scientific explanation skills only in the form of a description of a phenomenon.

Manik et al., (2020) and Prathiwi & Utami (2019) state that students must build and master critical thinking skills in chemistry learning. The basic laws of chemistry are one of the chemical materials that require critical thinking skills to learn, but these skills are not used when learning the material. This is explained by research by Fadillah et al., (2022) that students have a passive attitude toward the basic laws of chemistry because they are only given instructions to memorize and solve calculation problems without understanding the concept. Meanwhile, according to Mairoza & Fitriza (2021), the basic chemical law material is very abstract and concrete, so to understand the concept, critical thinking skills are needed. Connecting concepts with everyday life situations can increase understanding of concepts more deeply and support the learning process of the material being studied.

Based on a preliminary study at Senior High School 5 Banjarmasin, 88.5% of students had difficulty understanding chemistry materials with the teaching materials used and 69.2% of students looked for other supports to help them understand the material studied. Teaching materials and learning models used in learning have an important role in supporting learning through the Merdeka Curriculum. Developing teaching materials with appropriate learning models is a way for a teacher to motivate students to understand concepts and use them in everyday life (Dibyantini & Sulastri, 2023).

Research conducted by Putri & Sukarmin (2023) states that one way to improve critical thinking skills is with learning models and teaching materials used such as e-modules. Rohmatulloh et al., (2023) stated that the PBL learning model can help students improve critical thinking skills because students are faced with problems that must be solved. On the other hand, e-modules that interestingly present material, related to the real world and interactive help improve critical thinking skills.

Overcoming this, the researcher developed an e-module of basic laws of chemistry based on PBL to improve critical thinking skills. According to Darmayasa et al., (2018) and Mulyadi et al., (2019), learning materials that are systematically organized based on the curriculum and delivered via the Internet and electronic media are known as e-modules. E-modules are equipped with multimedia elements such as audio, video, and animation to enhance the learning experience. On the other hand, problem-based learning requires scientific methods to help students solve real problems relevant to life (Arends, 2008; Fidan & Tuncel, 2019; Susanto, 2020).

Previous research is the basis for taking this e-module development solution, (1) Mawati (2022) stated that problem-based chemistry e-modules effectively improve knowledge, attitudes, and skills so that they are suitable for use as learning resources, (2) Wulandari et al., (2020) found that the problem-based learning model affected critical thinking skills with a significance level <0.05, and (3) research by Izzania et al., (2024) stated that the e-modules developed were effective for equipping students' critical thinking skills. On the other hand, the development of this e-module brings novelty in terms of (1) technological integrity: the use of a platform in the development of e-modules shows the existence of technological integrity in education that reflects efforts to utilize digital technology and (2) the basis used: PBL helps students think critically and solve problems.

This development research certainly contributes to schools, teachers, and students in terms of (1) improving the learning process, (2) additional information related to e-module development, and (3) efforts to improve students' thinking skills. So the purpose of this study is to analyze the aspects of validity, practicality, and effectiveness of e-modules to improve critical thinking skills.

## METHOD

### Research Design

Figure 1 shows that the ADDIE model was used in this development research (R&D).

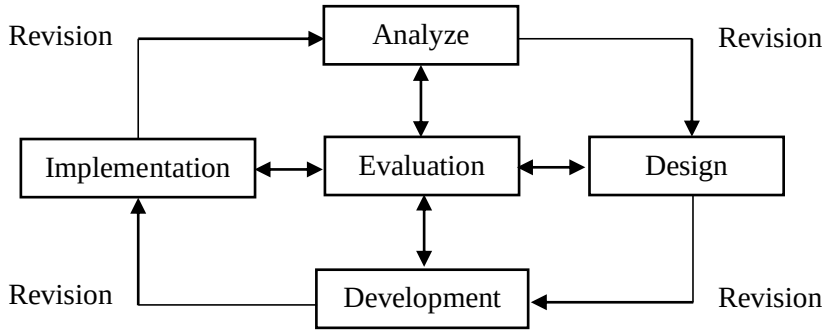


Figure 1. ADDIE Model

The analysis stage involved three types of analysis to start the research, namely (1) performance analysis was conducted to analyze basic problems and critical thinking skills faced in chemistry learning at Senior High School 5 Banjarmasin, (2) analysis of students and teaching material needs to be aimed at understanding the characteristics of students and learning needs at Senior High School 5 Banjarmasin and (3) analysis of facts, concepts, and procedures on learning materials.

The developed product was designed at the design stage. The process carried out, namely (1) collection of reference material for the basic laws of chemistry, (2) e-module framework design, (3) e-module prototype design, and (4) design of research tools and instruments. At the development stage, e-modules were made, and validated, individual and small group trials, and e-module modifications.

The results of the final revision made at the development stage are carried out at the implementation stage in class X-E and the evaluation stage is an action taken at each stage of ADDIE.

**Research Subject**

The test subjects of this development research were class X-E Senior High School 5 Banjarmasin totaling 36 students.

**Instruments and Data Analysis Techniques**

There are three types of data collection instruments, namely validity, practicality, and effectiveness instruments. The type of analysis used to evaluate product feasibility is validity analysis. This analysis evaluates 4 aspects, namely the feasibility of content, presentation, language, and media. Then to evaluate how easy the developed product is to use is known as practicality analysis. Meanwhile, the type of analysis used to assess the success of an action is effectiveness analysis. The calculation and assessment criteria for validity, practicality, and effectiveness can be seen as follows Formula 1.

$$Percentage = \frac{Number\ of\ Scores\ Awarded}{Maximum\ Sum\ of\ Scores}\ x\ 100\% \quad (1)$$

The percentage results obtained are then grouped based on the criteria for assessing the validity and practicality of the e-module, which can be seen in Table 1 and 2.

Table 1. Criteria for Validity of E-modules

| No. | Persentase Skor Validitas | Criteria | Information |
|---|---|---|---|
| 1 | 85.01 – 100.00 | Very Valid | Small Scale Revision |
| 2 | 70.01 – 85.00 | Fairly Valid | |
| 3 | 50.01 – 70.00 | Less Valid | Large Scale Revision |
| 4 | ≤ 50.01 | Invalid | Unusable |

(Akbar et al., 2015)

Table 2. Criteria for Practicality of E-modules

| No. | Percentage of Practicality Score | Criteria |
|---|---|---|
| 1 | 81 – 100 | Very Practical |
| 2 | 61 – 80 | Practical |
| 3 | 41 – 60 | Practical Enough |
| 4 | 21 – 40 | Not Practical |
| 5 | ≤ 20 | Not Very Practical |

(Akdon, 2015)

Then To determine the effectiveness of the e-module, the N-gain Formula 2 according to Meltzer was used.

$$<g>= \frac{S_{post}-S_{pre}}{S_{maks}-S_{pre}} \quad (2)$$

Table 3. N-Gain Score Categories

| No. | N-Gain Coefficient | Criteria |
|---|---|---|
| 1 | n > 0.7 | High |
| 2 | 0.3 ≤ n ≤ 0.7 | Medium |
| 3 | n < 0.3 | Low |

(Ramdhani et al., 2020)

Furthermore, the N-Gain values obtained were put into the N-Gain effectiveness assessment category as follows.

Table 4. N-Gain Effectiveness Interpretation Categories

| No. | N-Gain | Criteria |
|---|---|---|
| 1 | > 76 | Effective |
| 2 | 56 – 75 | Effective Enough |
| 3 | 40 – 55 | Less Effective |
| 4 | < 40 | Ineffective |

(Hake, 1999)

## RESULTS AND DISCUSSION

### Results

The Results at the analysis stage are as follows: (1) performance analysis: the conclusion obtained is that the cause of low critical thinking skills is that there is less practice in working on questions that refer to this variable and less confronted with issues that occur in everyday life, (2) analysis of students and teaching material needs: the conclusion obtained is that the skill level of students varies, then the teaching materials used make 88.5% of students feel difficult in learning chemistry, and 69.2% of students look for additional materials to help understand the material, (3) the analysis of facts, concepts, and procedures of the subject matter resulted in basic findings that can be used to formulate and set learning objectives in the e-module.

In the design stage, e-module design activities are carried out. The design process consists of four stages: (1) collection of reference material for the basic laws of chemistry, (2) e-module framework design, (3) e-module prototype design, and (4) design of research tools and instruments. This stage produces an e-module framework that is ready to be used in the next stage.

Creation/production, validation, individual and small group trials, and e-module modification are the development stages of this research. This process resulted in e-modules that are ready to be tested and research instruments that can be used. The materials in the e-module are arranged based on the ATP of chemistry subjects. The e-module sections developed are classified into: (1) the cover page contains the logo, base, material, and class information, author's identity, and relevant visualizations, (2) the beginning of the e-module contains an explanation of learning outcomes and learning objectives, an explanation of the features contained in the e-module, an explanation of the learning model and concept map, (3) the core part (learning activities) contains the stages of the

learning model, material, examples of daily life interests with material, example questions, independent practice and a summary, and (4) the closing section contains feedback, glossary, bibliography and author's bio. The following are the results of the development stage.

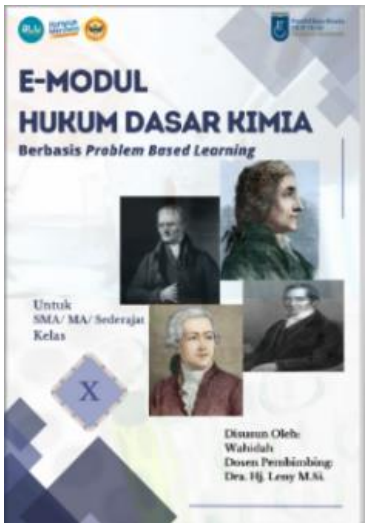


Figure 1. Cover Page

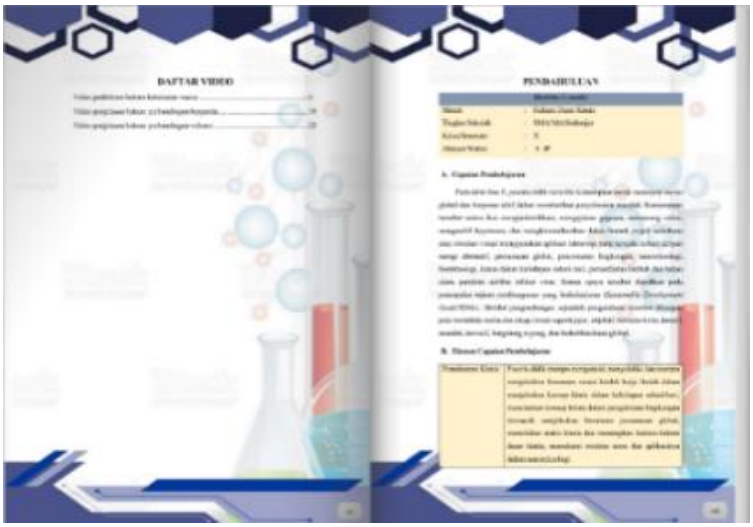


Figure 2. The Beginning of the E-module


Figure 3. Core Section (Learning Activities)


Figure 4. Closing Section

Evaluating learning products requires five experts to analyze the validity of the e-module. The aspects analyzed in this test are the feasibility of content, presentation, language, and media which consists of 45 questions. The results of the e-module validity test are shown in Table 5.

Table 5. Results of the E-module Validity Test

| No. | Aspects | Validator | | | | | Average | Percentage |
|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | | |
| 1 | Contents | 60 | 58 | 57 | 60 | 52 | 57.4 | 95.67 |
| 2 | Presentation | 70 | 69 | 69 | 70 | 59 | 67.4 | 96.29 |
| 3 | Language | 50 | 49 | 46 | 50 | 42 | 47.4 | 94.80 |
| 4 | Media | 45 | 40 | 41 | 45 | 36 | 41.4 | 92.00 |
| **Amount** | | **225** | **216** | **213** | **225** | **189** | **213.6** | **Very Valid** |
| **Percentage** | | **100** | **96** | **94.66** | **100** | **84** | **94.93** | |

Based on the data contained in Table 5, all aspects of the e-module show a very valid category. After the e-module was declared feasible by the experts, individual trials were conducted (5 students) and small groups (10 students). The average individual readability test was 81.6 with a very practical category. In individual trials, students gave suggestions, namely increasing the size of the writing on

the e-module, and simplifying complex language so that it is easy to understand and the colors used are brighter. Meanwhile, the small group trial received a score of 83 with a very practical category. Learners give suggestions and comments in the form of corrections on words that are typed incorrectly. The suggestions and comments given at the validation and trial stages were used as evaluation material for the researcher to improve the products developed before proceeding to the implementation stage.

The next step is the implementation stage, namely using e-modules in chemistry learning in class X-E. The results of this stage are in the form of questionnaire data for the practicality test and pretest and posttest data for the effectiveness test which are then processed into research results. The implementation and data related to the practicality test and effectiveness test can be seen in the following Figure 6, 7, 8 and Table 6 & 7.

Figure 6. Teaching and Learning Process

Figure 7. Pretest Activity

Figure 8. Posttest Activity

Table 6. Recapitulation of Practicality Test

| No. | Component | Score | Description |
|---|---|---|---|
| 1 | Readability | 84.23 | Very Practical |
| 2 | Student's Response | 86.56 | |
| 3 | Teacher Response | 80 | Practical |
| 4 | Teacher's Ability to Use E-modules | 86.44 | Very Practical |
| 5 | Learning Implementation | 85.05 | |
| **Average** | | **84.46** | **Very Practical** |

Table 7. Results of the Pretest and Posttest Critical Thinking Skills

| No. | Test | Average | N-Gain |
|---|---|---|---|
| 1 | Pretest | 21.74 | 81.15 |
| 2 | Posttest | 84.95 | |

Each stage of ADDIE conducts an evaluation stage. However, the evaluation was only conducted at the development stage, where researchers improved the e-module based on suggestions and comments from validators and during individual and small group trials. In addition, the evaluation was also conducted to complete the research and as a form of improvement so that the e-modules are ready for dissemination.

## Discussion

### *Product Validity*

The assessment given by the validator on the validity analysis concluded that the e-module received a very valid category. The content feasibility aspect received the highest score of 95.67, indicating that the e-module is by the 4 assessment indicators on the content feasibility aspect, while the media feasibility aspect received the lowest score compared to other aspects at 92.00. The low validation score given by the validator is because the media assessment is very crucial and affects appearance and attractiveness. This is relevant to the research of Fadhilah et al., (2020) the use of fonts, layouts, and illustrations can make teaching materials more interesting to read. Aspects of media assessment affect the clarity of the content presented and the proportionality of visuals, videos, texts, colors, and spacing by media standards (Luthfi et al., 2021).

Validation is needed because this is the process of assessing the feasibility of the product developed before the product is implemented in the learning process. E-module is learning material that contains explanations of specific knowledge, experiences, and practices, which are provided to help students understand certain material more easily. In the learning process, the use of teaching materials has a crucial role because it can help teachers achieve learning objectives, improve the quality of education, and make it easier for students to obtain knowledge and information related to the material being studied.

### *Product Practicality*

The purpose of product practicality is to find out how easy the product is to use. This analysis uses data from readability questionnaires, student responses, teacher responses, observations of teachers' ability to use e-modules, and observations of learning implementation (Syukra & Andromeda, 2019). The purpose of the readability questionnaire is to find out how well students understand the e-modules developed and the results of the readability questionnaire are 88.11. The student and teacher response questionnaires aim to measure reactions to the developed e-modules in terms of interest, material, and language. Student response obtained a score of 86.56 and teacher response obtained a score of 80. Furthermore, the observation of the teacher's ability to use the e-module obtained a score of 86.44 and the observation of learning implementation obtained a score of 85.05.

Ease of use of e-modules is an important factor in determining whether e-modules can be useful and appropriate teaching materials as an alternative to learning that can encourage the learning process. Practicality data plays a role in determining the value of the products produced such as aspects of ease of use, efficiency of learning time, and the benefits of e-modules (Safitri & Sari, 2022; Syukra & Andromeda, 2019). Based on the average practicality obtained of 84.46, it was concluded that the e-module was suitable for use as the main supporting teaching material in the learning process. This is in line with the explanation given by Asmiyunda et al., (2018) that research and development products are considered practical if respondents, namely teachers, students, and observers, state that the product can theoretically be applied in the field, which means that the practicality assessment indicators have been met.

### *Product Effectiveness*

This data analysis was conducted to test the critical thinking skills of X-E natural science students at Senior High School 5 Banjarmasin. The average obtained in the pretest was 21.74, indicating that students had difficulty in identifying questions and mastery of science knowledge that was not in-depth as stated in the test instrument, in addition, it is caused by the lack of practicing aspects of critical thinking skills in the learning process. The use of e-modules in learning causes an increase that can be seen in the average posttest, namely 84.95. This is in line with research of Kusasi et al., (2021) that the use of teaching materials used for direct student involvement will attract and increase the success of a learning process.

The interpretation of the effectiveness of N-Gain is in the effective category with a score of 81.15. Well-organized e-module materials equipped with additional information relevant to life can

influence N-Gain results. On the other hand, this e-module uses a problem-based learning model. The increase in critical thinking is certainly related to the learning model used so that it can improve the ability of students to explain and detail a problem. The learning process that invites students to solve authentic problems relevant to real life not only teaches them to receive information from the teacher, but also trains their ability to think critically, find solutions, process information, and communicate effectively during the learning process.

According to Syam (2020), with increasing age and the development of the social environment, each individual is often faced with increasingly complicated and complex problems, to face this situation and survive a person must have the ability to think critically and creatively. The cognitive process that involves consideration to analyze and evaluate is called critical thinking (Saputra et al., 2019). In the learning process, critical thinking plays an important role because it helps students build knowledge and cognitive reasoning skills and helps answer questions about how and why a concept is used (Ayun et al., 2020; Juliyantika & Batubara, 2022).

## CONCLUSION

The results of the research and discussion of the e-module of basic laws of chemistry based on problem-based learning to improve critical thinking skills show that the e-module is very valid with a validity score of 94.93, very practical with a practicality score of 84.46, an effective with an N-Gain score of 81.15. Suggestions for future researchers are that the developed e-modules can be accessed without using the internet and the testing of the developed products can be more than one school.

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