



## Development of a Chemistry Learning E-Module Based on Problem Based Learning on Reaction Rate Material to Improve Student Learning Outcomes

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### ABSTRACT

This study aims to develop a valid, practical, and effective Problem Based Learning (PBL) based chemistry e-module on reaction rate material for grade XI students at MA DDI Bontang in improving learning outcomes. This study uses the Research and Development (R&D) method with the ADDIE model which includes the Analyze, Design, Develop, Implement, and Evaluate stages. The resulting product is a PBL-based e-module as a more interesting and non-monotonous teaching material. Data collection techniques were carried out through observation, questionnaires, pretests, and posttests. The results showed that the developed e-module was very feasible to use based on validation by material experts of 90.0% and media experts of 87.0%. The use of PBL-based e-modules was also proven to be effective in improving student learning outcomes. The average posttest score of 85.4 was higher than the pretest score of 52.0. The t-test results showed that the t-count value of 19.146 was greater than the t-table of 2.042 at a significance level of 0.05, so there was a significant effect of the use of e-modules on student learning outcomes. In addition, student responses to the e-module were positive at 84.8%. Thus, the PBL-based e-module is feasible and effective for use in chemistry learning on reaction rates.

**Keywords:** e-module, PBL, ADDIE model, learning outcomes, reaction rate

### INTRODUCTION

Education plays a vital role in improving the quality of human resources and is an indicator of a nation's progress. Quality education will produce quality human resources, particularly students, as a result of the educational process. With superior human resources, a nation will have the ability to compete with other nations globally [1]. The development of education in the 21st century demands a learning process that is not only oriented towards mastering concepts, but also towards developing critical thinking skills [2], problem-solving, creativity, communication, and technological literacy [3]. The rapid development of information technology has brought significant changes in various aspects of life, including education. In response to these developments, 21st-century education is presented as a learning framework that focuses on developing students' learning abilities so they can adapt to the demands of the times and technological developments [4]. In a global context, it is crucial to prepare students to face the increasingly complex challenges of science and technology in everyday life [5]. With the development of the Industrial Revolution 4.0, the use of technology in education has become an unavoidable necessity. Technology provides opportunities for teachers to create more innovative,

interactive, and flexible learning experiences, thereby improving the quality of both the learning process and student outcomes.

The development of digital technology has driven the transformation of teaching materials from printed form to electronic teaching materials, one of which is e-modules. E-modules are digital teaching materials that are systematically arranged and can be used independently through electronic devices such as computers or smartphones [6]. The use of e-modules is considered more practical, flexible, and able to present more interesting learning because it is equipped with images, animation, audio, video, and interactive evaluation. Previous research shows that the use of e-modules can increase student motivation and learning outcomes [7], [8]. Therefore, e-modules are one of the alternative teaching materials that are relevant to be applied in learning in the digital era.

However, the implementation of technology-based learning in schools still faces various obstacles. Based on observations and interviews with 11th-grade chemistry teachers at MA DDI Bontang, it was discovered that the learning process is still dominated by lecture methods with the use of printed teaching materials. Students also do not have digital teaching materials that can be used flexibly for independent

learning anytime and anywhere. This condition causes students to be less active in the learning process and has an impact on low chemistry learning outcomes that have not reached the minimum completion criteria. This problem indicates the need for innovative teaching materials that can increase student engagement in learning.

In addition to the use of teaching materials, learning models are also an important factor in improving the quality of learning. One learning model that is appropriate to the demands of the 21st century is Problem Based Learning (PBL). PBL is a student-centered learning model through the presentation of contextual problems to train critical thinking and problem-solving skills [9]. PBL is an active learning method that focuses on investigating and solving complex real-world problems through direct learning experiences. This approach aims to encourage students to think critically, actively, and be involved in the learning process [10]. The PBL model is implemented by presenting real-world problems related to the learning material, so that students can learn actively and collaborate in finding solutions to the problems given [11]. PBL focuses on developing various abilities, such as reasoning, teamwork skills, and metacognition. In addition, PBL also aims to encourage independent learning and in-depth understanding, not just rote learning [12]. Through PBL, students are encouraged to investigate, discuss, analyze problems, and find solutions independently or in groups. Research shows that the application of PBL can improve critical thinking skills, problem-solving abilities, and student learning outcomes [13], [14].

In chemistry learning, the application of PBL is very relevant, especially for abstract materials. Chemistry is a branch of science that studies the structure and properties of matter, the transformation of one substance into another, and the energy that accompanies each change that occurs in the material [15]. One material that is quite abstract is the reaction rate. The material on reaction rates not only requires students to understand concepts and calculations, but also to relate chemical phenomena to everyday life. This material is often considered difficult by students because it is abstract and requires a deep conceptual understanding. The characteristics of the material on reaction rates require visualizations that can realistically depict the reaction process and the factors that influence the reaction rate. Therefore, learning resources are needed that can present the material on reaction rates more realistically, making it easier for students to understand the concepts being learned [16]. Therefore, teaching materials are needed that can help students understand concepts independently through the presentation of contextual problems and interactive learning activities. The integration of the PBL model into e-modules is expected to create a more meaningful and interesting learning experience and encourage students to actively construct their own knowledge. PBL-based e-modules have been shown to improve students' critical thinking skills through the presentation of an interactive

and engaging learning environment, thereby encouraging active participation and collaboration among students in the learning process. Various studies have also shown that the use of PBL-based e-modules provides a more significant increase in critical thinking skills compared to conventional learning [17]. The collaboration between PBL and e-modules provides a meaningful and enjoyable learning experience for students. The developed e-modules are designed to train problem-solving skills systematically through the stages of understanding the problem, analyzing it, planning a solution, implementing the solution, and conducting an evaluation [18].

Several previous studies have developed e-modules and implemented the PBL model in chemistry learning. However, research integrating PBL-based interactive e-modules on reaction rate material at MA DDI Bontang is still rare. In addition, the development of this e-module is designed not only as a digital teaching material, but also as an interactive learning medium that includes videos, animations, self-evaluation, and contextual problem solving that is close to students' lives. Thus, the novelty of this research lies in the development of a PBL-based chemistry e-module integrated with digital interactive features to improve learning independence, critical thinking skills, and student learning outcomes on reaction rate material. Based on this description, the researcher is interested in conducting research on the development of a Problem Based Learning (PBL)-based chemistry learning e-module on reaction rate material to improve the learning outcomes of grade XI students at MA DDI Bontang.

## RESEARCH METHODS

This study uses a research and development (R&D) design with the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The ADDIE model was chosen because it has systematic and comprehensive steps in developing learning products, thus being able to produce learning media that are appropriate to student needs and learning objectives. This study aims to develop a Problem Based Learning (PBL)-based chemistry learning e-module on reaction rates to improve student learning outcomes.

The research was conducted at MA DDI Bontang from July to December 2022. The target population was 31 eleventh-grade students. The subjects were selected because students at that level have already studied reaction rates, thus meeting the needs of the e-module development. Data were collected through several data collection techniques, including expert validation, tests, observations, and questionnaires. Expert validation was conducted to determine the feasibility and validity of the developed e-module. Validation was conducted by material experts and media experts using a pre-designed validation sheet. Furthermore, a test was used to determine the effectiveness of the e-module on student learning outcomes. The test was a written multiple-choice test. To determine user responses to the

developed e-module, the researchers also used student and teacher response questionnaires..

The research instruments used included expert validation sheets, observation sheets, test questions, and teacher and student response questionnaires. The expert validation sheets consisted of material validation sheets and media validation sheets, which were used to assess the quality of the content, presentation, appearance, and suitability of the e-module before it was implemented in learning. The observation sheets were used to observe teacher and student activities during the learning process using the e-module. Multiple-choice test questions were used to measure improvements in student learning outcomes after using the e-module. Meanwhile, the response questionnaire was used to determine teacher and student responses to the attractiveness, ease of use, and benefits of the e-module in learning.

The data obtained were then analyzed descriptively quantitatively and qualitatively. Expert validation data were analyzed to determine the feasibility of the product developed as a learning medium. Observation data were used to describe the learning process during the use of the e-module. Teacher and student questionnaire response data were analyzed to determine the level of attractiveness, ease, and usefulness of the product. The test results were analyzed to determine the effectiveness of the e-module in improving student learning outcomes on the reaction rate material. The effectiveness of the e-module was analyzed using a paired sample t-test statistical test on students' pretest and posttest scores. This test was conducted to determine whether there was a significant

difference between student learning outcomes before and after using the Problem Based Learning (PBL)-based e-module.

**RESULT AND DISCUSSION**

Based on the validation results by material experts presented in Table 1, the average feasibility of the chemistry e-module on reaction rates was 90%. This percentage indicates that the e-module is in the very good category. Of the 20 assessment instrument items, 15 received a very good score and 5 received a good score. The high level of material feasibility is influenced by several aspects, namely the suitability of the material to basic competencies, indicators, learning objectives, learning videos, example questions, practice questions, and evaluation questions. In addition, the completeness of the material and the validity of the concepts presented in the e-module were also assessed as very good. From a linguistic aspect, the readability of the writing, the use of terms appropriate to the level of student understanding, and the use of sentences that comply with Indonesian language rules and do not create double meanings also support the quality of the e-module. In terms of presentation, the learning steps are easy to understand, the learning activities support students' independent learning, and the practice questions are aligned with the learning objectives and the references used are relevant to the material. Thus, the clarity and readability of the material, as well as the suitability of the indicators and learning objectives in the e-module, can facilitate students' understanding of the material, thus optimally achieving learning objectives.

**Table 1.** Results of Material Expert Validation

No	Feasibility Aspect	Score	Maximum Score
1	Content Feasibility	42	45
2	Discussion Feasibility	22	25
3	Presentation	26	30
Total Score		90	100
Average Percentage		90 %	

The results of the material expert validation showed a content feasibility score of 42 out of a maximum score of 45, language feasibility of 22 out of 25, and presentation aspect of 26 out of 30, so that the total score obtained was 90 out of a maximum score of 100 with an average percentage of 90%. These results indicate that the developed e-module has met the feasibility criteria in terms of material, language, and presentation so that it is suitable for use in the learning process. In addition to the material aspect, the quality of the e-module was also reviewed from the media aspect to ensure that the appearance and design used are able to optimally support the student learning process.

The results of the media expert validation showed that the e-module obtained an average feasibility percentage of 87% and was in the good category. This assessment indicates that the developed media has met the design and display aspects that support the learning process. Several factors that contributed to the high level of media feasibility include

the title color that contrasts with the background, the use of moderate font variations, an attractive e-module display that can increase student learning interest, clear instructions for using the media, and ease of use of the navigation buttons. In terms of the module cover design aspect, the e-module obtained a score of 17 out of a maximum score of 20, while in terms of content design aspect, it obtained a score of 44 out of a maximum score of 50. The total score obtained was 61 out of a maximum score of 70 with an average percentage of 87%. These results indicate that the e-module has met the criteria for learning media that is suitable for use in the learning process.

**Table 2.** Media Expert Validation Results

No	Feasibility Aspect	Score	Maximum Score
1	Cover Design	17	20
2	Content Design	44	50
Total Score		61	70
Average Percentage		87 %	

After going through the validation stage, the e-module was tested through a small group trial involving 10 students of class XI MA DDI Bontang. Based on the results of the assessment questionnaire, an average percentage of 90.5% was obtained, indicating that the e-module was in the very feasible category. In terms of appearance, a percentage of 88% was obtained, indicating that students considered the level of text readability good and the module's appearance attractive. In terms of material, a percentage of 90% was obtained, indicating that the material was easy to understand, the terms used were clear, the sentences

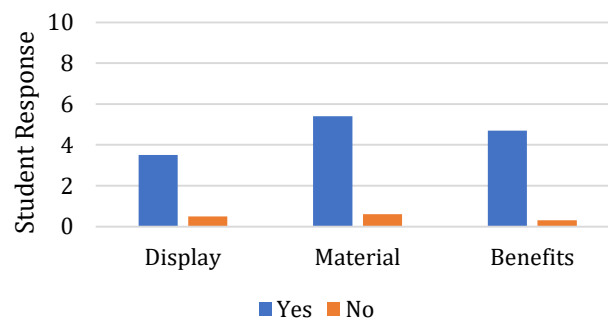
were easy to understand, the material was systematically arranged, and the illustrations used were appropriate to the material presented. Meanwhile, in terms of usefulness, a percentage of 94% was obtained, indicating that the use of the e-module provided an interesting learning experience, facilitated the learning process, and helped smooth learning. Overall, the results of the small group trial showed that the e-module received a positive response from students with a percentage of assessments above 80% in each aspect, so the e-module was declared suitable for field trials.

**Table 3.** Results of Small Group Trial Data Analysis

No	Feasibility Aspect	Score	Maximum Score	Percentage (%)
1	Appearance	35	40	88
2	Material	54	60	90
3	Usefulness	47	50	94
Score Total		136	150	
Average Percentage		90.5		

In terms of material, a percentage of 90% was obtained, indicating that the majority of respondents believed the material in the e-module was easy to understand, the terms used were clear, the sentences used were easy to understand, and the presentation of the material was systematically arranged and supported by illustrations that were appropriate to the learning material. Therefore, the e-module was categorized as very suitable in terms of material. Meanwhile, in terms of usability, a percentage of 94% was obtained, indicating that the use of the e-module was able to

provide an interesting learning experience, facilitate student learning, and help smooth the learning process, so it was included in the very suitable category. Based on the assessment results for each aspect, it can be concluded that the e-module received a positive response from students, categorized as very good. This is evidenced by the percentage of student questionnaire responses that were above 80% in each assessment aspect, so the e-module was declared suitable for field trials. The results of the small group trials are not only presented in tabular form but also visualized in Figure 1.



**Figure 1.** Results of small group trials

The next field test was conducted on 21 students of class XI MA DDI Bontang using an assessment questionnaire. Based on the results obtained, the average percentage of e-module feasibility reached 94.3% and was included in the very feasible category. In the appearance aspect, a percentage of 94% was obtained, indicating that students considered the e-module's appearance attractive and had a good level of readability. In the material aspect, a percentage of 95%

was obtained, indicating that the material was easy to understand, the use of terms was clear, sentences were easy to understand, the material was systematically arranged, and illustrations were in accordance with the learning material. Meanwhile, in the usefulness aspect, a percentage of 94% was obtained, indicating that the e-module was able to provide an interesting learning experience, facilitate the learning process, and improve the smoothness of learning. Based on the assessment

results, it can be stated that the e-module received a positive response from students because more than 80% of students gave positive assessments in each

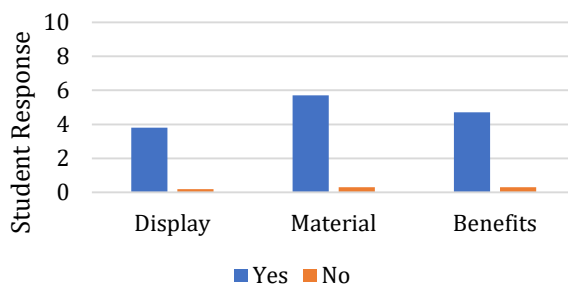
aspect. This indicates that the developed e-module is very suitable for use in chemistry learning on the topic of reaction rates.

**Table 4.** Field Test Results

No	Feasibility Aspect	Score	Maximum Score	Percentage (%)
1	Appearance	79	84	94
2	Material	120	126	95
3	Usefulness	99	105	94
Score Total		298	315	
Average Percentage				94.3

In terms of material, a percentage of 95% was obtained, indicating that the majority of respondents believed the material in the e-module was easy to understand, the terms used were clear, the sentences used were easy to understand, and the presentation of the material was systematically arranged and supported by illustrations that were appropriate to the learning material. Therefore, the e-module was categorized as very suitable in terms of material. Meanwhile, in terms of usability, a percentage of 94% was obtained, indicating that the use of the e-module was able to

provide an interesting learning experience, make it easier for students to understand the material, and help the learning process run smoothly, so it was included in the very suitable category. Based on the assessment results for each aspect, it can be stated that the developed e-module received a positive response during the field test phase, because more than 80% of students gave a positive assessment of the e-module. In addition to being presented in tabular form, the results of the field test are also visualized in Figure 2.



**Figure 2.** Field trial results

E-modules were implemented in the learning process for 31 students to determine their effectiveness in improving student learning outcomes. The e-module implementation was conducted over four meetings. Before the e-module learning process was implemented, students were first given a pretest consisting of 25 questions to measure their initial abilities. After the e-module learning process was completed, students were given a posttest to determine the improvement in

learning outcomes after using the e-module. Based on the results of data analysis, it was found that the average score of student learning outcomes before using the e-module was 52.0 with a standard deviation of 8.94. After learning using the e-module, the average score of student learning outcomes increased to 85.4 with a standard deviation of 5.71. Descriptively, these results indicate an improvement in student learning outcomes after using the e-module in learning.

**Table 5.** Descriptive Statistics

Test	Mean	N	Std. Deviation	Std. Error Mean
Pretest	52.00	31	8.94	1.61
Posttest	85.42	31	5.71	1.03

This improvement in learning outcomes is supported by the practical, efficient, easy-to-use, and easily distributed characteristics of e-modules. Furthermore, e-modules are interactive, facilitating learning navigation and integrating various supporting media, such as images, audio, and video, which can help students better understand the material. E-modules also have the advantage of complementing the function of

printed modules while supporting digital learning more effectively. Thus, the use of e-modules not only supports technology-based learning processes but also improves student learning outcomes in the reaction rate material. To determine whether the difference in average learning outcomes before and after using the e-modules was significant, a paired t-test was conducted, as presented in Table 6.

**Table 6.** Paired Samples Test

Paired Differences	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pretest- Posttest	-33.42	9.72	1.75	-19.15	30	0.00

Based on the results of the paired sample t-test in Table 8, the average difference between the pretest and posttest was -33.42 with a standard deviation of 9.72 and a standard error of 1.75. The negative value of the average difference indicates that the average posttest value is higher than the average pretest value, indicating an increase in student learning outcomes after using the e-module. The analysis results also show a calculated t value of -19.15 with a degree of freedom (df) of 30 and a significance value (Sig. 2-tailed) of 0.00. Because the significance value is less than 0.05 ( $0.00 < 0.05$ ), there is a significant difference between student learning outcomes before and after using the e-module. Thus, the use of the e-module has been proven to have a positive effect on improving students' chemistry learning outcomes in the reaction rate material. This increase in learning outcomes indicates that the e-module is able to help students understand the material more effectively through interactive, systematic, and easily accessible presentation of material. The use of e-modules allows students to learn independently with the support of digital learning media such as images, videos, and interactive navigation that can increase student motivation and engagement in learning. The results of this study are in line with research [19] which states that guided inquiry-based e-modules are effective in improving student learning outcomes with a high effectiveness category. In addition, research [20] also explains that e-modules that are designed systematically and interactively are able to improve student learning outcomes because they can make the learning process more interesting and not boring. This finding is also supported by research [21] which shows that the use of e-modules provides a significant difference to student learning outcomes based on the results of the paired sample t-test. Therefore, the e-module developed in this study is declared effective for use in chemistry learning on the topic of reaction rates.

## CONCLUSION

From the research results, it can be concluded that the development of PBL-based chemistry learning e-modules obtained 90% validation results from material experts and 87% from media experts with a very good category. Based on the results of the student questionnaire, the use of PBL-based chemistry learning e-modules obtained very practical student responses. Based on the results of the pretest and posttest, there was an increase in student learning outcomes so that PBL-based chemistry learning e-modules were very effective for improving student learning outcomes on reaction rate material. The researcher's suggestion based on the results of the research that has been conducted is that for parties interested in developing the product further, they can add material or use other chemical materials and use different classes so that the resulting product is more comprehensive, because this product only contains reaction rate material and only one class.

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