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THE DEVELOPMENT OF INNOVATIVE LEARNING MATERIAL WITH A PROJECT TO IMPROVE STUDENT'S CRITICAL THINKING SKILLS IN THE TEACHING OF REDOX TITRATION

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Abstract
Self-directed learning has become popular in higher education worldwide in recent years. As a result, students may have difficulty understanding higher education standards. Therefore, innovative learning materials that are relevant and easy to understand by students and provide opportunities for developing student's character so that they are competent in developing their knowledge capacity independently through high-level thinking skills such as critical thinking. Through the research and development method using the ADDIE Model, teaching materials are created by integrating the PjBL learning model to measure product feasibility scores, students' critical thinking abilities, and know student responses and learning outcomes. Based on the validation results, the average value of the validation results obtained was 89% (valid). After testing the product, it was discovered that the student response was 87.68% (good), the average critical thinking ability score was 87.36, indicating an increase and the average learning outcomes obtained by students were from 56.80 to 87.38, indicating an increase. Overall, the integrated teaching materials for the PjBL learning model on Redox Titration material are suitable.

Keywords: *Innovative; Learning Material; Critical Thinking Skills; Redox Titration*

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INTRODUCTION

Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have the skills needed by themselves and society [1]. National education in Indonesia has been designated as one of the national development sectors that make the nation's life more intelligent. It has a vision of realizing the education system as a solid and authoritative social institution to empower all Indonesian citizens to become quality human beings. As one of the learning plans used today, the curriculum needs to implement various learning strategies to equip students with knowledge appropriate to the subjects they study [2].

Therefore, innovative learning materials that are relevant and easy for students to understand are in great demand [3]. Suitable learning materials must present subject matter based on curriculum demands and developments in science and technology and can bridge learning to achieve predetermined competencies. Innovative teaching material is a learning resource adaptable to student needs [4]. Flexible to analyze and consider various factors, including student qualities such as intellectual, emotional, and spiritual capacities and learning barriers [5].

Teaching materials are all materials, whether in the form of information, tools, or texts, that are arranged systematically and display a complete figure of competencies that will be mastered by students and used in the learning process to plan and review learning implementation [6]. Furthermore, innovative teaching materials should provide opportunities for developing students' character to build their knowledge capacity independently through high-level thinking skills such as critical thinking, creativity and decision-making, and problem-solving [7]. Critical thinking is considered to help in solving problems and making decisions, while problem-solving is a process where individuals try to overcome the problem they face to achieve goals [8].

As a chemical discipline, analytical chemistry is concerned with the qualitative and quantitative characterization of chemicals. This is very important in almost every part of our lives because chemicals are present in everything we use. This course is exciting and demanding because it can be a method for developing critical thinking skills that integrate theory and practice, as well as knowledge and abilities in using instruments for analytical purposes [9].

Variations in learning methods and models can be used to improve chemistry courses' teaching and learning processes. One learning innovation is the use of a project-based learning model. Project-based learning is learning that requires an extended period, focusing on student activities to be able to understand a concept or principle by carrying out in-depth investigations into a problem, finding relevant solutions, and implementing them in project work so that students experience meaningful learning process by building his knowledge [10]. The project-based learning method allows students to work independently or in groups to produce project results from everyday life problems [11].

Several previous studies on new chemistry teaching materials found that these teaching materials had an effect, showing that the development of innovative chemistry teaching materials improved students' critical thinking skills, analytical chemistry skills, and knowledge [9]. Other research shows that developing innovative learning materials can increase creativity in laboratory experiments, encourage students to learn freely, create a more enjoyable learning environment, and improve student performance in knowledge and psychomotor elements [12]. Based on the facts and problems above, project-based learning with teaching materials is one option that can be used to develop student understanding. This study aims to provide an innovative learning material resource integrated with a Project-based learning model on teaching redox titration to measure product feasibility scores, measure students' critical thinking abilities, know student responses, and measure student learning outcomes [13].

METHOD

This research belongs to the type of research and development research and development (R&D) to the kind of ADDIE model (Analysis, Design, Development, Implementation, Evaluation) developed by Dick & Carry [14]. This model is an approach that helps teachers design efficient and effective teaching by applying the ADDIE model process to any instructional product. In addition, this systematic process is represented in the acronym ADDIE, an essential component in the learning design process, namely Analysis, Design, Development, Implementation, and Evaluation. Each phase in the ADDIE model is related and interacts with the others. Researchers use the ADDIE development model to develop learning material. However, this research is limited to the implementation stage only. Researchers modify the development model according to needs.

This research was conducted at the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan. This research was conducted in the odd semester from February to May of the 2022/2023 academic year. The respondents involved in this study were Chemistry Education students with a Bachelor's degree in semester IV who were studying Qualitative and Quantitative Chemistry courses consisting of one class of Bilingual Chemistry 2020.

The data obtained from this study are qualitative and quantitative data obtained from assessments and revisions to the Redox Titration teaching materials, which are integrated with the project-based learning model. The qualitative analysis obtained is input from expert validators to improve the product being developed. In contrast, quantitative analysis is carried out by calculating expert validation results, student responses, learning outcomes, and students' critical thinking abilities.

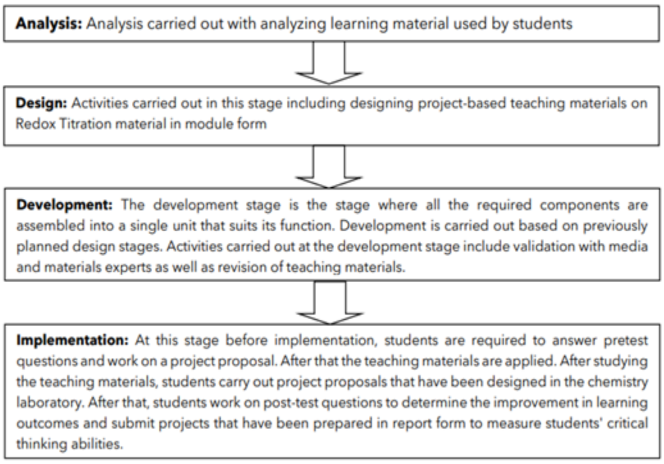

Figure 1. E-Module for practicum of acid-base titration

Data Analysis

To analyze the feasibility of the teaching materials, the teaching materials were validated using a validation sheet to media experts and calculated by the following formula:

$$\bar{x} = \frac{\sum fm}{\sum fa} \times 100\%$$

Information:
$\bar{x}$: average score
$\sum$fm : the number of times the activity appears
$\sum$fa : the total frequency of all activities

Table 1. Score categorization

Score Interval	Category
3.51-4.00	Very High
2.06-3.50	High
1.70-2.59	Low
0.00-1.69	Very Low

Student Response Analysis

The data obtained from a questionnaire of student's responses is carried out using the following equation:

$$NP = \frac{R}{SM} \times 100\%$$

Information:
NP : The percent value sought or expected
R : Raw scores obtained by students
SM : The ideal maximum score of the test in question

Table 2. Score Categorization

Score Interval (%)	Category
86-100	Excellent
76-85	Good
60-75	Fairly good
55-59	Bad
0-54	Very Bad

Critical Thinking Skills

The mean and standard deviation were calculated to analyze the students' critical thinking skills. The mean obtained is representative of the data set that is closest to the actual measurement results.

$$X = \frac{\sum x}{n}$$

Where,

x : Mean
∑x : Data score
n : Amount of data

The standard deviation is used to see how close the data distribution is to the average or mean.

$$S = \sqrt{\frac{\sum(x_i - \bar{x}}{n}}$$

Where,

S : Standard Deviation
x_i : Value of x in i data
x : Mean
n : Frequency

Analysis of Student Learning Outcomes

Normality Test

The normality test is a test used to determine whether the sample used in the study comes from a population that is normally distributed or not. The normality test used in this study is the Shapiro-Wilk test with the help of IBM SPSS 25 software. The Shapiro-Wilk test can be used when the number of samples is small.

The decision-making criteria for the SPSS output results are as follows:

If *sig.* > 0.05 (5%), then $H0$ is accepted, Ha is rejected, with the conclusion that the sample comes from a normally distributed population.

If *sig.* ≤ 0,05 (5%), then $H0$ is rejected, Ha is accepted, with the conclusion that the sample comes from a non-normally distributed population.

Hypothesis testing

Hypothesis testing is carried out to determine whether students' critical thinking skills have increased. If the data obtained in the research is usually distributed and homogeneous, then the hypothesis test used is the parametric statistical test, namely the one-sample T-test. The parametric statistical test in this study will be carried out using the one-sample t-test formula with the help of IBM SPSS 25 software [15]. The terms used for acceptance/rejection $H0$ as follows:

If sig. < α (0.05), then $H0$ is rejected, and Ha is accepted.

If sig. > α (0.05), then $H0$ is accepted, and Ha is rejected.

N-gain Test

The learning outcomes are then analyzed using normalized gain. The formula for normalized gain is as follows:

$$g = \frac{sf - si}{100 - si}$$

Where,

g : Normalized gain
SF : Posttest score
si : Pretest score

The normalized gain value was analyzed according to the following table:

Table 3. Normalized Gain Criteria

Criterion	Conclusion
g ≥ 0.7	High
0.3 ≥ g > 0.7	Moderate
g < 0.3	Low

RESULTS AND DISCUSSION

Media and Materials Expert Validation

Project-based teaching materials result from learning innovations in extracted material, which are validated by expert validators, namely chemistry lecturers. The research instruments used in project standardization in teaching media and material are presented in the form of a questionnaire based on SNPT; in this questionnaire, the aspects assessed in teaching materials are (1) Content Eligibility Aspects, (2) Language Eligibility Aspects, (3) Presentation Eligibility Aspects, (4) Graphical Eligibility Aspects. The data obtained at this stage is qualitative in the form of comments and suggestions for improvement.

Based on the average value of the eligibility test of teaching materials, the questionnaire results from the validator obtained the following values.

Table 4. Validity scores of the media and content

Assessment Component	Score (%)	Level of validity
Content Eligibility	90.0	High
Language Eligibility	86.5	High
Presentation Eligibility	88.2	High
Graphic Eligibility	91.2	High
Overall	89.0	High

From the results obtained, the eligibility of the content received an average score of 90%, with the eligibility criteria being very valid for use without revision. Then, language feasibility, with a score of 86.5%, is included in the very valid eligibility criteria. The feasibility score is 88.2%, which is very valid. On graphic eligibility, a score of 91.2% is obtained; namely, the eligibility criteria are very valid for use without revision. The average rating for the teaching material is 89%, which shows that the teaching material is very valid.

Students Critical Thinking Skills

Teaching and learning activities have been implemented using project-based learning for Redox Titration. Students make projects according to the procedures given in the teaching materials. Project-based learning that has been created is then carried out to build student independence in learning analytical chemistry and to build students' critical thinking skills in achieving the competencies required in analytical chemistry.

Table 5. Achievement of Students' Critical Thinking Ability

No.	Aspects of Critical Thinking	Descriptor	Student Achievements
1.	Interpretation	skills to design projects for the topic of Redox Titration, choose the right equipment and target samples for contextual work, and understand the information contained in data from observations.	84.38 ± 9.38
2.	Analysis	Skills in analytical work in a project related to a given topic, preparing necessary equipment in Redox Titration separation and selecting relevant data, process and predicting identified results, and concluding logically with precision.	90.22 ± 3.09
3.	Inference	Able to work on projects in the correct order, starting from setting up instruments, taking notes and recording results, solving problems in the laboratory, maintaining work safety, and identifying the meaning of inferential relationships between data, questions, and science concepts.	87.45 ± 4.15
4.	Evaluation	Able to write project reports based on the format provided in the learning materials, able to express scientific views on the results and discuss the results data and chemical phenomena obtained in the project, have skills in presenting inventions and findings from working projects, and assessing data quality and providing explanations representative.	87.49 ± 7.86
Average			87.38 ± 6.12

After doing the project, students then complete and improve the project report that has been done before. Students' critical thinking skills on completed projects can be measured with an average of 87.38. Based on the average obtained, it can be seen that there has been an increase, and it has been proven that students can think critically when carrying out projects.

Class Room Implementation

After the implementation stage is complete, the student's pretest and posttest data are obtained. The data that has been received will be further processed as follows.

Normality Test

The data obtained was then analyzed using the Shapiro-Wilk normality test using the SPSS 25 application to determine whether the data was normally distributed.

Table 6. Test of Normality

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.110	18	.200*	.955	18	.503
Post-test	.132	18	.200*	.965	18	.691

Based on the normality test from Shapiro-Wilk in Table 6, the pretest p-value is 0.503, more significant than 0.05. This shows that the pretest data from the sample is usually distributed. Both data of the pretest and posttest are usually distributed as indicated by the p-value of 0.503 and 0.691, respectively ($p>0.05$)

Hypothesis Test

Testing of student learning outcomes after using the module was tested using the paired sample T-Test using SPSS 25 software. Based on the SPSS analysis results, the score obtained shows p-Sig. (2-tailed) = 0.000. Because p-value = 0.000 < α = 0.05. This means there is a difference in student learning outcomes before and after being taught with innovative project-based learning resources in Redox Titration.

N-Gain Test

A test was used to evaluate the students' understanding of the project-based teaching materials. The initial stage was carried out by giving a pretest with Redox Titration material, then distributing project-based teaching materials, and finally giving a posttest to see student understanding after using project-based teaching materials. Based on the calculation results, statistical data obtained from student learning outcomes are summarized in the descriptive statistics table in Table 8.

Table 7. Summary of Descriptive Statistics of Student Learning Outcomes

Pretest	Mean	55.61	1.4532
	Variance	38.01	
	Std. Deviation	6.165	
	Minimum	46.00	
	Maximum	66.00	
Posttest	Mean	86.77	0.9481
	Variance	16.18	
	Std. Deviation	4.022	
	Minimum	80.00	
	Maximum	94.00	

Based on Table 7, student learning outcomes show that the average pretest results obtained are 55.611 ± 6.165, and the average posttest results are 86.78 ± 4.02, which shows an increase from the previous pretest results.

The gain value was measured to investigate the improvement in student learning outcomes. The gain value can be calculated by subtracting the posttest scores from the pretest scores, then after the ideal score, where the formula subtracts 100 from the student's initial or pretest scores.

After these two values are obtained, additional values can be obtained using a predetermined formula, namely the difference between the posttest and pretest scores divided by the ideal score sought so that the results can be seen in Table 9. In the attached data, the percentage of the gain value can be calculated and adjusted according to the existing categories, as seen in Table 4.8 below.

Table 8. The mean N-Gain

Stages	Mean
N-Gain	0.71
N-Gain Percentage	71%

From the table of N-gain test results above, it can be seen that the average n-gain score is 0.71, where the n-gain score of $g \geq 0{,}7$ is included in the high category. This shows the effect of teaching materials on redox titration material on student learning outcomes.

Student Responses

After students use teaching materials and work on projects contained in teaching materials, the next stage is to give a response questionnaire to determine the level of satisfaction in using these teaching materials. 18 CESP 2020 students filled out the response questionnaire and included 23 indicator items.

Table 10. Percentage of Student Responses to the Use of Project-Based Teaching Materials

No	Statement	Satisfaction Level (%)
1	I find it easy to understand the concept of redox titration through PjBL	94.40
2	It is clear to me how this learning material relates to what I have learned	87.80
3	The teaching materials contain useful information that initiates my curiosity	85.60
4	Presentation of material and assignments are clear, sequential and direct my thinking concept so that I understand more about this material.	91.10
5	I feel challenged to learn the concept	87.78
6	I feel free to explore my abilities through PjBL	76.67
7	By reading this project-based teaching material, I have a better understanding of the practicum procedures	91.11
8	this project-based teaching made me more creative in designing projects and doing assignments	84.44
9	With project assignments, I can formulate the problem correctly	84.44
1	The PjBL model makes me creative in designing project assignments	83.33
11	PjBL makes me more active and successful in solving complex problems	87.78
12	The assignments given in the teaching materials improve my skills in making time allocations for project completion	88.89
13	Project assignments in these teaching materials make me skilled at collaborating and developing communication skills	85.56
14	Having project assignments in teaching materials makes me skilled at managing resources and equipment to complete assignments	90.00
15	The existence of project-based teaching materials makes the theory that I have learned so far more concrete	91.11
16	I feel more active in learning	85.56
17	With varied assignments, I am free to express my creative ideas	86.67
18	The pictures, colors, and illustrations in this teaching material made me more interested in learning	94.44
19	project assignments in this teaching material train my ability to think more critically	92.22

No	Statement	Satisfaction Level (%)
20	The project assignment in this teaching material trains me to analyze a problem	85.56
21	The assignment of projects in these teaching materials trained my thinking concepts to become more focused	85.56
22	Assignment projects in this teaching material I am more trained in independent learning	85.56
23	The project assignments in this teaching material practice my skills in compiling the things needed when working in the laboratory	91.11

Based on the results of the student response questionnaire to the use of teaching materials, the average result was 87.68%. Based on these results, it can be seen that students feel satisfied and can better understand project-based innovative teaching materials using multimedia and redox titration material.

CONCLUSION

Based on the standardization of project-based teaching materials on the Redox Titration material that has been carried out, the validation was obtained based on content eligibility of 90%, language eligibility of 86.5%, presentation eligibility of 88.25%, and graphic feasibility of 91.25%. The average eligibility of the module is 89%. In accordance with the SNPT validation criteria, this figure is in the range of 76-100%, which indicates that the module is valid.

The pretest and posttest data show that the data from the sample is normally distributed shown by the p-value of the pretest is 0.503 and the posttest is 0.691, which is greater than 0.05. For the hypothesis test it showed that p-Sig.(2-tailed) = 0.000. Because p-value = $0.000 < \alpha = 0.05$. This means there is a difference in student learning outcomes before and after being taught with innovative project-based learning resources in the teaching of Redox Titration.

Standardized teaching materials were tested by giving a pretest and obtained an average pretest score of 55.611 ± 6.165 and a posttest of 86.78 ± 4.02. This shows an increase with a pretest and posttest gain value of 0.71, where the n-gain score of $g \geq 0,7$ is included in the high category.

Then, the results of critical thinking that students have obtained before using teaching materials is 56.80, and the results of critical thinking after using teaching materials is 87.38, which shows an increase. The average effectiveness of the teaching materials that have been given is 87.68%. Based on these results, students feel satisfied and able to understand project-based innovative teaching materials using multimedia on redox titration material.

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