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Development of STEM-*Based Problem Based Learning* E-Module on Electrolysis Cell Material for Class XII SMA/MA

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Development of STEM-Based Problem Learning E-Module on Electrolysis Cell Material for Class XII SMA/MA. This study aims to develop an electrolysis cell e-module based on STEM Integrated problem-based learning. The type of research used is research and development or Research and Development (R&D). The development model used is the plomp model which consists of 3 stages, namely: preliminary research (early investigation stage), (2) development or prototyping phase (development or prototyping stage), and (3) assessment phase (trial and assessment stage). This research is limited to the development stage, namely the validity test and practicality test. The research instrument used was a validity and practicality questionnaire. The E-Module was validated by 5 validators while the practicality test was carried out by 3 chemistry teachers and 16 students of class XII MIPA SMAN 10 Padang. The data from the validity test were analyzed using the Aikens'V formula and the practicality was analyzed using descriptive statistics. Validation is carried out in two stages. Stage I obtained an average content validity test of 0.76 with an invalid category and an average media validity test of 0.77 with an invalid category, so that stage II validation was carried out, where the average content validity test was 0. 91 with a valid category and the media validity test average of 0.90 with a valid category. While the practicality test for teachers is 0.91 and students are 0.91 with a very high practicality category. Thus, it can be concluded that the problem-based integrated STEM-based electrolysis cell e-module produced for class XII SMA/MA students that was developed is valid and practical.

Keywords: E-Module, Problem Based Learning, STEM, Electrolysis cell, Plomp Model

Albstralk: Pengembalngaln E-Modul Berbasis Problem-Based Learning Terintegrasi STEM Pada Materi Sel Elektrolisis Untuk Kelas XII SMA/MA. Penelitian ini bertujuan untuk mengembangkan e-modul sel elektrolisis berbasis *problem based learnin*g Terintegrasi STEM. Jenis penelitian yang digunakan adalah penelitian dan pengembangan atau *Research and Development* (R&D). Model pengembangan yang digunakan adalah model plomp yang terdiri dari 3 tahap, yaitu: *preliminary research* (tahap investigasi awal), (2) *development or prototyping phase* (tahap pengembangan atau pembuatan prototipe), (3) *assessment phase* (tahap uji coba dan penilaian). Penelitian ini dibatasi pada tahap pengembangan, yaitu uji validitas dan uji praktikalitas. Instrumen penelitian yang digunakan adalah angket validitas dan praktikalitas. E-Module divalidasi oleh 5 validator sedangkan uji praktikalitas dilakukan oleh 3 orang guru kimia dan 16 orang peserta didik kelas XII MIPA SMAN 10 Padang. Data hasil uji validitas dianalisis dengan menggunakan formula Aikens'V dan kepraktisan dianalisis menggunakan statistik deskriptif. Validasi dilakukan sebanyak dua tahap. Tahap I didapatkan rata-rata uji validitas konten sebesar 0,76 dengan kategori tidak valid dan rata-rata uji validitas media sebesar 0,77 dengan kategori tidak valid, sehingga dilakukanlah validasi tahap II, dimana didapatkan rata-rata uji validitas konten sebesar 0,91 dengan kategori valid dan rata-rata uji validitas media sebesar 0,90 dengan kategori valid. Sedangkan uji kepraktisan guru sebesar 0,91 dan peserta didik sebesar 0,91 dengan kategori kepraktisan sangat tinggi. Dengan demikian, dapat disimpulkan bahwa e-modul sel elektrolisis berbasis *problem based learning* terintegrasi STEM yang dihasilkan untuk peserta didik kelas XII SMA/MA yang dikembangkan sudah valid dan praktis.

Kaltal Kunci: *E-Modul, Problem Based Learning, STEM, Sel elektrolisis, Model plomp*

- **INTRODUCTION**

Learning in the 21st century does not escape the touch of technology, especially internet-based ones. Today's students are millennials and generation Z who are very familiar with information and communication technology. Therefore, teachers must be able to adapt to the characteristics of students. Based on this, 21st-century learning must apply critical thinking skills to train and assist students in solving problems (Puspitarini, 2022). Critical thinking ability is a very important ability possessed by students because having this ability can help us think rationally in overcoming the problems we face (Karim, 2015). Critical thinking skills can be created through the Problem Based Learning model.

Problem-Based Learning (PBL) learning model is a learning model that initially presents real-world problems in gathering information, integrating new knowledge through group work in improving higher-order thinking skills, problem-solving skills, and gaining essential knowledge and concepts from the material lesson (Djamas, 2012). Problems in PBL use real problems experienced in everyday life and are open as contexts for students to develop problem-solving skills and creative thinking to solve problems and build new knowledge. One of the learning approaches that can overcome real-world problems experienced by students in everyday life is the STEM approach. Where, students do not just memorize concepts, but rather how to understand science concepts and their relation in everyday life (Subramaniam et al., 2012). The STEM integrated Problem-Based Learning model is one of the recommended learning models in the 2013 curriculum learning.

According to (Kurniasih, 2014) the 2013 curriculum can encourage students to have critical, creative, and innovative thinking skills. The 2013 curriculum is set to improve the quality of Indonesian education at all levels which are assessed through three domains of competence, namely: knowledge, attitudes, and skills. The 2013 curriculum implementation focuses on students active activities through scientific processes. Where, the goal is that learning does not only create students who have knowledge competence but is also able to create students who have good attitudes and skills (Kemendikbud, 2013).

One of the chemical materials that require visualization to explain abstract concepts and needs to be carried out in the laboratory is material about electrolysis cells (Priatmojo Utomo, 2014). Electrolysis cells are one of the chemical materials studied in class XII SMA/MA in odd semesters. Electrolytic cells are closely related to everyday life. Submission of this material really requires learning critical thinking and analysis to find your own answer to a definite answer to a problem. Currently, learning in schools is carried out in limited face-to-face or blended learning. For that, we need a learning media that can improve the knowledge and skills of students, one of which is e-modules. E-modules are independent learning materials that are systematically regulated in electronic format to help the learning process (Kemendikbud, 2017).

Based on the results of observations that have been made by giving questionnaires to 6 chemistry teachers in class XII SMA/MA, namely 2 chemistry teachers at SMAN 2 Padang, 2 chemistry teachers at SMAN 10 Padang, and 2 chemistry teachers at SMA Pertiwi 1 Padang, and 108 The students of class XII MIPA at SMAN 2 Padang, SMAN 10 Padang, and SMA Pertiwi 1 Padang obtained that: (a) 62% of students considered chemistry difficult to understand, (b) 64.8% of students considered chemistry material, especially cells. electrolysis is difficult to understand, (c) 55.6% of students use worksheets, 29.6% use printed books and only 11.1% of students use e-modules, (c) 76.9% of students do not do practical work to be able to understand the concept of chemical materials, especially electrolysis cells due to the Covid-19 pandemic, (d) 83.3% of teachers still use printed teaching materials in chemistry learning, especially electrolysis cells, (e) 100% of teachers and 85.2% of students are interested using e-modules in the learning process yes, especially for the material of the electrolysis cell.

This is because the teaching materials used have not shown the stages of the problem-based learning model. Therefore, it is necessary to develop teaching materials in the form of a problem-based learning module to increase student' understanding. Based on these problems, the authors want to research to develop teaching materials in the form of e-modules based on learning-based learning integrated STEM in electrolysis cell, as well as analyzing the level of validity and practicality of the developed e-modules.

- **METHOD**

The type of research used is research and development or Research and Development (R&D). The development model used is the plomp development model. The Plomp development stages are (1) preliminary research (early investigation stage), (2) development or prototyping phase (prototyping stage), and (3) assessment phase (trial and assessment stage) (Plomp & Nieveen, 2013). This research was only carried out to test the validity and practicality of the developed e-module. The subjects of this research were 2 chemistry lecturers at FMIPA UNP, 3 FT UNP lecturers, 3 chemistry teachers, and 16 students in class XII MIPA SMAN 10 Padang.

The first step in this research is preliminary research (early investigation stage). The purpose of this initial investigation stage is for an in-depth analysis of the material. Where the analysis carried out at this stage is needs analysis, context analysis, literature study, and conceptual framework development. Needs analysis is carried out to find out the extent of the basic problems experienced by teachers and students in the field so as to create solutions that are in accordance with the conditions at school. Context analysis is carried out by examining the curriculum and syllabus that will be used in developing the e-module. A literature study was conducted to find out the essential knowledge needed in product development. The conceptual framework is carried out to connect the problems that have been identified with the literature study that is used as a reference in developing an e-module based on STEM Integrated Problem-Based Learning on electrolysis cell material.

The next stage is the prototyping stage (prototyping stage). At this stage, it is done by designing a product in the form of an e-module which is equipped with formative evaluation. The stages carried out for formative evaluation based on Tesmer, namely self-evaluation (self-evaluation) on prototype I, expert review (expert assessment) and one-to-one evaluation (one-on-one test) on prototype II, small group evaluation (small group test) on prototype III, and field test (field test) on prototype IV. This research is limited to the small group evaluation stage (small group test).

The instrument used in this study was a validation and practicality questionnaire. The validation sheet is used to assess the validity of the developed e-module which consists of 30 aspects of the content validation assessment and 15 aspects of the media validation assessment. Where this assessment is compiled using a Likert scale from 1 to 5/. This validation sheet is addressed to the chemistry lecturer at FMIPA UNP, the FT UNP lecturer, and the chemistry teacher at SMAN 10 Padang. The practicality sheet is used to determine the level of practicality of using the developed e-module. This practicality sheet is addressed to chemistry teachers and students at SMAN 10 Padang.

The data obtained from the results of the validity and practicality tests on the product were analyzed using Aiken's V formula. Mathematically, the Aiken's V index is:

$$V = \frac{\sum s}{[n\,(c-1)]}$$

$$s = r - lo$$

Information:
V = validator agreement index
r = validator choice category score
n = number of validators
lo = lowest value of validity assessment (lo = 1)
c = highest validity assessment number (c=5) (Retnawati, 2016).

Based on the Aiken's V scale, the validity assessment criteria can be seen in Table 1.

Table 1. Validity Based on Aiken's V Scale

iken's V scale	Category
V < 0,8	Invalid
V ≥ 0,8	Valid

(Aiken, 1985)

Practical sheets were obtained from the provision of student response questionnaires which were analyzed using the formula:

$$P = \frac{f}{N} \times 100\%$$

Information:
P = product practicality
f = total value obtained from the questionnaire
N = maximum value in the questionnaire

Table 2. Practicality Category

Score	Criteria
86% -100%	Very Practical
76% - 85%	Practical enough
60% - 75%	Practical
55% - 59%	Less Practical
≤54%	Not Practical

(Yunus, Y. 2020)

- **RESULT AND DISCUSSION**

A. Research Result

1. Preliminary research

At this stage, the analysis of the needs and analysis of context, literature study, and development of the conceptual framework is carried out. The results of each stage carried out in the preliminary research stage are:

Needs and context analysis

The needs analysis was carried out using the results of observations in schools in the form of giving questionnaires to 108 students from SMAN 2 Padang, SMAN 10 Padang, and SMA Pertiwi 1 Padang as well as direct interviews with chemistry teachers in the three high schools. The results of giving questionnaires and interviews to teachers and giving questionnaires to students showed that teachers still use printed books, and worksheets in the learning process so that the teaching materials used are not in accordance with 21st-century learning.

Context analysis is carried out by analyzing the 2018 revised curriculum in 2013, where learning is centered on students, independent learning, and students are skilled in using technology in the learning process. In addition, context analysis is carried out on Basic Competencies (KD) on electrolysis cell that can be reduced into an indicator of Competency Achievement (GPA). The basic competencies for electrolysis cell material are KD 3.6 Applying stoichiometry of redox reactions and Faraday's law to calculate quantities related to electrolysis cells and KD 4.6 Presenting a design procedure for plating metal objects with a certain layer thickness and area.

Study of literature

This stage is carried out to obtain and understand information from reference sources both from books, articles, and journals regarding e-modules based on STEM-integrated problem-based learning on electrolysis cell material. The results obtained from the literature study are: (1) the components of the e-module are referenced from the guide for the preparation of e-modules issued by the Ministry of Education and Culture in 2017, and (2) the criteria or content of the material in the developed product is referenced from textbooks, (3) the syntax The problem-based learning model used consists of five syntaxes, namely orientation of students to problems, organizing students to learn, guiding individual/group investigations, developing and presenting work, analyzing and evaluating the problem-solving process, (4) the development model used is The plomp development model consists of three stages, namely: preliminary research, prototyping phase, and assessment phase.

Conceptual framework development

At this stage, a conceptual framework is made by identifying, detailing, and systematically compiling the main concepts that are embraced and used as references in the development of STEM-based integrated problem-based learning e-modules on electrolysis cell material. It was found that the main concepts that must be mastered by students include: the working principle of an electrolytic cell, reactions of an electrolytic cell, and the calculation of Faraday's law in an electrolytic cell, as well as an analysis of the concepts of the material presented in the form of a concept analysis table to facilitate map making. electrolytic cell concept.

2. Prototyping Phase

The Prototyping Phase produced four prototypes which were evaluated with the formative evaluation in each prototype. However, this research was only carried out until practicality.

Prototype I

Prototype I is a prototype resulting from the design and realization of the preliminary research stage. The prototype I result is an e-module based on problem-based learning integrated STEM on electrolysis cell material for class XII SMA/MA which has several components such as cover, instructions for use, learning competencies, concept maps, and evaluation activity sheets, and answer keys.

Prototype II

Prototype II was produced after a formative evaluation was carried out in the form of a self-evaluation of prototype I that had been previously designed. Self-evaluation is carried out with a checklist system for components that must be in electronics. If there are still parts that are missing, it is necessary to revise them so as to produce prototype II.

Prototype III

Prototype III is produced from expert reviews and one-to-one evaluation of prototype II. The purpose of conducting an expert review is to determine the validity of the developed e-module. Validation was carried out by 5 validators for material experts and media experts. The material expert validators consisted of 2 chemistry lecturers from FMIPA UNP and 3 teachers at SMAN 10 Padang. While the media experts consisted of 2 chemistry lecturers from FMIPA UNP and 3 lecturers from FT UNP. A validation questionnaire is an instrument used to collect validity test data. The evaluation given by the validator to the e-module for content validation is in the form of content components, linguistic components, presentation components, and graphic components. The data obtained were analyzed using the Aiken's V formula. The data analysis of the content validation of e-modules based on STEM-based integrated problem-based learning on phase I and II electrolysis cell material can be seen in table 3.

Table 1. Content Validation Results

Rated aspect	**Phase I**	**Phase II**
	Score V	Score V
Content component	0,75 (Invalid)	0,88 (Valid)
Linguistic component	0,85 (Valid)	0,98 (Valid)
Serving component	0,73 (Invalid)	0,91 (Valid)
Graphic component	0,71 (Invalid)	0,89 (Valid)

Meanwhile, the media validity test is carried out to determine aspects of appearance, programming aspect, and aspects utilization. Validation Analysis of e-module media data based on problem-based learning integrated STEM in phase I and II electrolysis materials can be seen in table 4.

Table 2. Media Validation Results

Rated aspect	*Phase I*	*Phase II*
	Score V	Score V

Display aspect	0,74 (Invalid)	0,93 (Valid)
Programming aspect	0,76 (Invalid)	0,90 (Valid)
Utilization aspect	0,80 (Valid)	0,88 (Valid)

Based on table 3 in the validation phase I, there are three invalid components, namely the content component, the presentation component, and the graphic component, so phase II validation is needed so that all components are valid. In stage II validation, the validated e-module is valid in all its components.

Based on table 4 in validation phase I there are two aspects that are not valid, namely the display aspect and the programming aspect that phase II validation is needed so that all aspects are valid. In stage II validation, the validated e-module is valid in all its aspects. In addition to the validity test, a practicality test was also carried out on students and teachers of SMAN 10 Padang. Practicality tests were conducted to see the usability and practicality of the products developed. Where the results of teacher practicality can be seen in table 5.

Table 3. Teacher Practical Results

Rated aspect	Persentase	Practicality category
Ease of use	90%	Very practical
Time efficient	90%	Very practical
Benefit	92%	Very practical

Table 4. Student Practical Results

Rated aspect	Persentase	Practicality category
Ease of use	92%	Very practical
Time efficiency	89%	Very practical
Benefit	91%	Very practical

Table 5 shows that the Problem-Based Learning e-module integrated STEM on electrolysis cell material has a high level of practicality. In addition to teachers, students also have high practicality which can be seen in table 6.

B. Discussion

The research that has been carried out aims to develop a product in the form of an e-module based on STEM integrated Problem Based Learning on electrolysis cell material. E-modules are the result of innovation from ICT-based modules and have advantages compared to print modules, namely the presence of images, videos, and animations (V K Cheva, 2019). The quality of the developed product can be seen through 3 criteria, namely validity, practicality, and effectiveness. However, this research is only limited to practicality.

The validity of the e-module is determined by using an assessment questionnaire sheet that has been assessed by 5 material experts with a questionnaire assessment in the form of content validation consisting of 30 items, as well as questionnaire validation by media experts who were assessed by 5 media experts with a validation questionnaire assessment consisting of 15 items. The assessment of these five validators is based on the opinion of Sugiyono (2013: 172) which states that to test the validity, expert opinions (judgment experts) can be used with a minimum of three people.

Based on the results of the validation of the content components in stage I, the average value was obtained at 0.75 so the e-module was declared invalid so stage II validation had to be carried out. Where stage II validation has increased in several aspects with an average value of 0.88 with a valid category. This shows that the e-module developed is in accordance with the demands of Core Competencies (KI), Basic Competencies (KD), and learning objectives to be achieved. This is in accordance with the opinion of Purwanto (2006: 138) that the aspect of content feasibility includes the suitability of the material contained in the module with KI, KD, and learning objectives to be achieved and the material provided is in accordance with the abilities of students.

Based on the results of the validation of the linguistic component at this stage, the average value was obtained at 0.85. Different results were obtained in stage II validation with an increase, where the average value was obtained at 0.98 so that the e-module was declared valid. This shows that the developed e-module already uses Indonesian Spelling (EBI) rules, and is clear and communicative so that students can understand the material well. The requirement for good teaching materials is to be able to describe something using language that is easily understood by students according to their level of knowledge and age (Permatasari and Yerimadesi, 2020). This is also in accordance with the characteristics of the e-module, which is user-friendly.

Based on the results of the validation of the presentation components in stage I, the average value was obtained at 0.73 so the e-module was declared invalid so, and stage II validation had to be carried out. Where stage II validation has increased in several aspects with an average value of 0.91 with a valid category. This means that the electronics that have been developed are designed by the indicators and learning objectives that have been formulated.

Based on the validation results of the of the graphic component in phase I the average value is obtained at 0.71 so that the e-module is declared invalid so that the validation of phase II must be carried out. Where validation phase II has increased in several aspects with an average value of 0.89 with a valid category. This shows that the developed e-module has an attractive appearance, both in terms of cover, font, font size, background, layout, and images. So that the e-module makes it easy for users to understand the contents of the e-module. This is in accordance with one of the characteristics of the e-module, which is user-friendly.

Based on the results of the validation of the display aspect in stage I the average value was obtained at 0.74 so the e-module was declared invalid so stage II validation had to be carried out. Where stage II validation has increased in several aspects with an average value of 0.93 with a valid category. This shows that the developed e-module has a good display composition.

Based on the results of the validation of the programming aspects in stage I, the average value was obtained at 0.76 so the e-module was declared invalid so stage II validation had to be carried out. Where validation phase II has increased in several aspects with an average value of 0.90 with a valid category.

Based on the results of the validation of the utilization aspect in stage I the average value was obtained at 0.80 so that the e-module was declared valid but there was one aspect that was not valid so stage II validation was carried out again. Where stage II validation has increased in several aspects with an average value of 0.88 with a valid category.

Based on the average obtained from data processing, the average results of content and media validation of the three components of the STEM-based problem-based integrated electrolysis cell e-module from the validator are 0.91 and 0.90, respectively, with valid categories.

So, for the next stage, a one-to-one evaluation is carried out. Based on the results of one-to-one evaluation interviews conducted by 3 Class XII students of SMAN 10 Padang, it can be concluded that the e-module cover, color design, and e-module display are attractive, and the fonts on the e-module are clearly legible, the video is available. can guide students in finding concepts, presenting the material and the language used is easy to understand, the problems and pictures presented make it easier for students to answer questions to find and understand concepts, and the stages of learning presented to make it easier for students to carry out the learning process and make it easier for them to understand electrolytic cells.

Practicality tests are carried out to find out how practical the products developed in the field are (Fadhillah & Andromeda, 2020). The results of the e-module practicality assessment data were analyzed using descriptive statistics. The data on the practical results of the problem-based integrated STEM-based electrolysis cell e-module were obtained from a small group trial by 16 students of SMAN 10 Padang with different abilities and a practical test from 3 chemistry teachers at SMAN 10 Padang.

In the aspect of ease of use, the e-module has average practicality of 90% with the category of very practical practicality from chemistry teachers and 92% of students in the category of very practical practicality. This shows that learning based on integrated electrolysis e-modules is easy to use. Teaching material is said to be practical if easy to use (Mudijo, 1995: 59).

In the aspect of learning time efficiency was obtained from the teacher's response by 90% with a very practical category of practicality, while the response from students was obtained by 89% with a very practical category of practicality. This shows that the e-module developed is efficient in terms of time to be used in the learning process.

In the aspect of the benefits of the STEM-based problem-based integrated electrolysis cell e-module, a score of 92% was obtained from the teacher's response in the very practical category of practicality, while the value obtained from the students was 91% in the very practical practicality category. This shows that the developed e-module can help students learn independently and can understand the material through videos, animations, pictures, and questions contained in the e-module. This is to the Ministry of Education and Culture (2017: 3) that e-modules are one of the teaching materials presented in electronic form that can be used by students to learn independently. The e-module also helps the teacher's role as a facilitator. The average practicality test from 3 chemistry teachers was obtained by 91% with a very practical practicality category, while the practicality test for 16 students of class XII SMAN 10 Padang was 91% with a very practical practicality category.

- **CONCLUSION**

Based on the research and data processing that has been carried out, it can be seen that the STEM integrated Problem-Based Learning-based electrolysis cell module developed has a high validity level of 0.91 for content validation and 0.90 for media validation, as well as high practicality of 0.91 teacher practicality and 0.91 for student practicality.

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