JPPIPA 10(7) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of E-Module Acid-Base Based on Problem Based Learning Oriented Chemo-Entrepreneurship to Improve Student's Critical Thinking Skills

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Received: February 11, 2024
Revised: June 05, 2024
Accepted: July 25, 2024
Published: July 31, 2024

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DOI: 10.29303/jppipa.v10i7.7943

Abstract: Acid-base is one of the important materials in chemistry learning. Based on preliminary analysis, it is known that students have not properly understood the concept of acid-base. This study aims to develop an acid-base e-module, analyze its validity, practicality, and effectiveness on critical thinking skills. This research method is development research with the Plomp development model. The e-module was validated by 5 valitadors. The practicality test was conducted on 28 students and 3 teachers. The effectiveness of the e-module is seen from the increase in critical thinking test score from 57 students. Validity and practicality were analyzed using Aiken's V, while effectiveness was analyzed with N-Gain. The results showed that the developed e-module had a validity value of 0.89 with a valid category; a practicality value of 0.87 by students and 0.97 by teachers with a practical category. The effectiveness results show that the e-module has an effect on students' critical thinking skills, as evidenced by the N-Gain score of the experimental class of 0,7 with a fairly effective category while the N-Gain score of the control class is 0,4 with a less effective category. Thus, the developed e-module is declared valid, practical, and effective.

Keywords: Acid-base; Chemo-entrepreneurship; Critical thinking; E-module; Problem based learning

Introduction

Education in the modern digital era must be able to improve the quality of learning so that students' abilities develop beyond just mastering the subject matter. To deal with rapid and complex social and economic changes, students need to have critical thinking skills. In addition, entrepreneurial skills are increasingly valued as a way to create independent, creative and adaptive individuals.

Chemistry is one of the subjects that is often considered challenging by many students, especially in acid-base material. This material includes concepts that require an understanding of chemical principles as well as the ability to apply them in everyday life (Aslama et al., 2023). However, many students only understand the concepts theoretically and struggle to apply them in the real world. The gap between theory and practical application can be addressed through acid-base learning that trains students' critical thinking skills and is combined with entrepreneurial knowledge.

One of the cognitive abilities required by today's learning is the capacity for critical thought (Muhammad et al., 2023). Preferences for critical and analytical thinking in particular have been studied as potential barriers to the acceptance of conspiracy theories (Cannito et al., 2024). Critical thinking needs to be integrated into curriculum content, instructional

How to Cite:
Putri, H. S., Oktavia, B., Yerimadesi, & Alizar. (2024). Development of E-Module Acid-Base Based on Problem Based Learning Oriented Chemo-Entrepreneurship to Improve Student's Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 4033–4039. https://doi.org/10.29303/jppipa.v10i7.7943

strategies, and grade level sequencing in order to produce successful critical thinkers (Alsaleh, 2020).

In the context of education, entrepreneurship is an important science to introduce to students. This is reflected in the 2013 curriculum and the independent curriculum that teaches Workshop and Entrepreneurship subjects at the Senior High School level. Chemistry learning can also provide entrepreneurial insights. Entrepreneurship integrated into chemistry is usually called chemo entrepreneurship, a contextual learning approach associating science with everyday phenomena (Prayitno et al., 2024).

According to Lestari et al. (2019) and Afwa et al. (2020), and Ni'mah et al. (2023), Chemo-entrepreneurship (CEP) is a method of teaching chemistry that can give students experience and be beneficial. CEP technique is a form of contextual learning in which students are able to connect the subject matter to real-world situations.

Since critical thinking and CEP are considered important for students, more innovative and engaging learning strategies are needed to teach acid-base concepts while training students' critical thinking and introducing entrepreneurship. One effective way is to utilize technology in the preparation of teaching materials, namely through the use of E-Modules.

E-module is one type of module that is presented by utilizing electronics. E-module is a form of presentation of teaching materials that are systematically arranged and presented in electronic format, where each learning activity in it is connected by links as navigation (Kemendikbud, 2017).

The e-module presentation can be arranged according to the syntax of the learning model. One of the learning models that can be used to study acid-base material is problem-based learning (PBL). One educational innovation that empowers, refines, tests, and continuously develops students' thinking abilities is problem-based learning. With the use of groups or teams, this learning paradigm enables students to maximize their critical thinking abilities (Nurdyansyah et al., 2016). Based on the results of research conducted by Khoirulloh et al. (2024)that critical thinking can be improved by implementing the video-assisted Problem Based Learning (PBL) model on momentum and impulse material.

The purpose of developing PBL-based and CEP-oriented acid-base e-modules, in addition to helping students to understand acid-base material, is to train students to think critically. By using e-modules during learning, it is expected that students' ability to think critically will increase. Critical thinking ability is a cognitive ability that can help students make decisions. In making decisions, students with this ability will be able to consider various points of view and factors (Jamaluddin et al., 2020; Wijayanti et al., 2020).

Based on the results of interviews with chemistry teachers at SMA Negeri 6 Tanjung Jabung Barat, it is known that in learning chemistry, especially acid-base material, they still use teaching materials in the form of package books. Package books are not specifically designed for problem-based learning. The use of package books is considered unable to help students train critical thinking, this can be seen in the results of the initial critical thinking test which obtained an average score of 30 with a category of less. Therefore, a teaching material is needed that can help students train critical thinking as well as introduce them to entrepreneurship.

The development of e-modules with the PBL model and CEP approach in chemistry learning has been carried out and shows valid and practical results, such as in the material on the colligative properties of solutions (Annisa et al., 2021) and buffer solutions (Manurung et al., 2023).

Based on this, researchers developed an acid-base e-module based on Problem Based Learning Oriented Chemo-Entrepreneurship to improve students' critical thinking skills.

Method

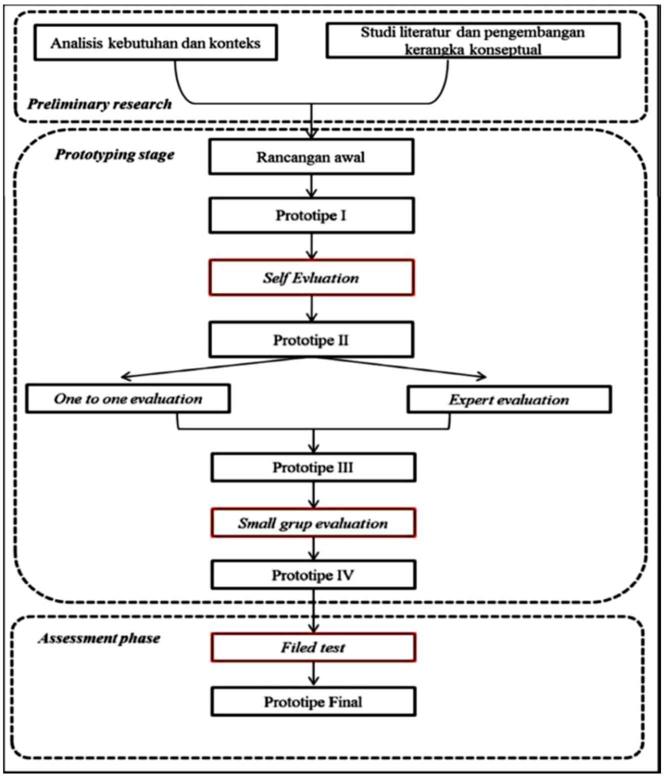

Figure 1. Plomp development model procedures

This type of research is known as development research (R&D), which aims to investigate, design, create and test the credibility of the products created (Sugiyono, 2018). The subjects of this research were UNP chemistry lecturers and chemistry teachers as validators. Practitioners include chemistry teachers and students from class XI IPA SMAN 6 Tanjung Jabung Barat.

The E-Module was developed using Plomp's development model which consists of three main stages; Preliminary Research, Prototyping Stage, and Assessment Phase. Plomp's stages can be seen in Figure 1.

Preliminary Research

Preliminary research is focused on analyzing or identifying problems and needs in chemistry learning (Plomp et al., 2013).

Prototyping Phase

In the prototyping phase, four prototypes were made throughout the prototyping phase, and each one underwent formative appraisal. This examination is intended to improve the quality of the products produced. The resulting prototype is an acid-base e-module that employs problem-based learning and a chemo-entrepreneurship strategy. The e-module is intended to help students enhance their critical thinking ability in acid-base study.

Formative evaluation was carried out between prototypes I and IV to improve product quality prior to field testing. Self-evaluation, one-on-one assessment, expert review, and small group discussion comprise formative evaluation. This evaluation's goal is to assess the acid-base e-module's quality, which blends chemo-entrepreneurship with problem-based learning.

Assessment Phase

In the assessment stage, the field test is used to conduct a (semi) summative evaluation to determine whether the product can be used in the field and whether its quality can be improved (Plomp, 2013). The field test was conducted by sending questionnaires to chemistry teachers and high school students to be used as a practical test.

Validity and Practicality of e-modules were analyzed using Aiken's V formula as shown in the Equation 1.

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

With: s = r-lo, where lo is the lowest validity score, c is the highest validity score, r is the validator score, and n is the number of validators.

Aiken's V value coefficient ranges from 0-1. If the result obtained is close to 1, the higher the validity value. Conversely, if the result obtained is close to 0, the validity is lower (Aiken, 1985).

Critical thinking assessments were administered to the experimental class and the control class in order to assess the efficacy of the e-module. The experimental class used e-modules that had been valid and practical in learning, while the control class used existing teaching materials at school.

Tests were given before and after the lesson. Pre-test and post-test result were analyzed using the N-Gain formula to see the effectiveness of e-modules in improving critical thinking skills. The N-gain formula is shown in the Equation 2.

$$\text{N} - \text{Gain} = \frac{\text{Posttes score} - \text{Pretest score}}{\text{Max skor} - \text{Pretest score}} \quad (2)$$

Based on the results obtained, the categories can be grouped based on Table 1.

Table 1. Interpretation of N-Gain

N-Gain Score	Category
$g \geq 0.70$	High
$0.70 < g \geq 0.30$	Medium
$0.30 > g$	Low

Result and Discussion

Preliminary Research

Needs and context analysis, literature research, and conceptual framework development were some of the steps taken during the preliminary research stage. To conduct a needs analysis, two chemistry teachers were interviewed and a needs questionnaire was distributed to students of class XI IPA SMA Negeri 6 Tanjung Jabung Barat. The results of the needs analysis obtained information that the teaching materials used during chemistry learning are printed books, there are no teaching materials specifically for problem-based learning models, there are no electronic-based teaching materials, there are no teaching materials that fully help train students' critical thinking, and there are no PBL-based acid-base e-modules oriented to CEP in schools. Based on the results of this analysis, teaching materials in the form of PBL-based acid-base e-modules oriented to CEP were developed in accordance with the curriculum.

Context analysis is an analysis of the abilities that students must master during learning according to the independent curriculum. Based on the analysis of the General Learning Outcomes of chemistry phase F (CPU), it is derived into Specific Learning Outcomes (CPK) for acid-base material, the intention is that students can use the concept of acid-base in everyday life. CPK is then analyzed to be reduced to Learning Objectives (TP) and Flow of Learning Objectives (ATP).

In the literature review, sources or references about the activity are gathered. Books, journals, and online publications are all acceptable references.

Prototyping Phase

The results of prototype I in the form of e-modules are compiled based on the results of preliminary research analysis. Prototype I was then subjected to self-evaluation, where the e-module was organized based on the e-module components which consists of; cover, instructions for use, competencies to be achieved, activity sheets composed of problem-based learning syntax, worksheets, self-assessment sheets, chemo-entrepreneurship discourse, evaluation, answer key, bibliography (Kemendikbud, 2017). The results of the self-evaluation analysis show that the e-module already contains the components of the e-module. So that prototype II is obtained.

Prototype II was then assessed by experts to test its validity. The validity aspect of the e-module consists of four components; content component, linguistic component, construct component, and graphical component (Depdiknas, 2008). The validity test was conducted by five validators.

Table 2. E-Module Validity Results

Components	V	Category
Content	0.88	Valid
Construct	0.88	Valid
Language	0.91	Valid
Graphics	0.88	Valid
Average	0.89	Valid

The results of the validity of the content component obtained an average Aiken's V value of 0.88 with a valid category. This is in accordance with the opinion of Purwanto (2013) that the content component includes the suitability of the material contained in the e-module with the learning objectives and abilities of students.

The construct component was 0.88 with a valid category. The assessment of the construct component relates to the content of the e-module arranged in accordance with the steps of the problem-based learning model, which consists of; orienting students to the problem, organizing students to learn, guiding investigations, developing and presenting work, and analyzing and evaluating the problem-solving process (Sofyan et al., 2017). So it can be said that the e-module developed is in accordance with the syntax of the problem-based learning model.

On the linguistic component, one of the six motivational design concepts for text and picture is readability, which is achieved by employing straightforward language that is simple to grasp. This contributes to the learning media's overall favorable impression (Junia et al., 2023). The results of the validity of the language component obtained an average Aiken's V of 0.91 with a valid category, so it can be said that the e-module has been prepared with good Indonesian language, simple, and easy to understand.

Finally, on the graphical component, the average Aiken's V value obtained was 0.88 with a valid category. It can be said that the overall design of the e-module developed is attractive. According to Hersandi et al. (2017), Aesthetic elements include things like typeface selection, arrangement, display designs, graphics, photographs, and photography (Yovita et al., 2023). Of the four components, the overall average was 0.89 with a valid category. So it can be concluded that the e-module has been declared valid by validators, so prototipe III was produced.

Next, a small group trial was conducted with six students. The small group trial used a practicality questionnaire. The results of the small group trial analysis can be seen in Table 3.

Table 3. Small Group Practicality

Aspect	V	Category
Ease of Use	0.92	Valid
Time Efficiency	0.94	Valid
Benefit	0.89	Valid
Average	0.91	Valid

The small group test was conducted on the e-module in the form of prototype III. The practicality test was conducted on six students who had different ability levels, namely high, medium and low ability levels. There are three aspects that are carried out in the small group practicality test, namely, the ease of use aspect, the time efficiency aspect, and the benefit aspect.

In the ease of use aspect, the Aiken's V average value of 0.92 was obtained in the practical category. This means that the material presented in the e-module is easily understood by students.

The practicality of the time efficiency aspect, obtained an average Aiken's V value of 0.94 with a practical category. This shows that the use of e-modules in learning makes learning time more efficient and students can learn according to their own learning speed (Wahyuni et al., 2021).

In the benefits aspect, the average Aiken's V value obtained was 0.89 with the practical category. This shows that the use of e-modules in learning helps students in learning independently, the existence of worksheets can measure students' understanding of the material presented, and by using e-modules students' interest in learning increases. This is consistent with research findings Adriani et al. (2021) that show students' motivation to learn can be raised by utilizing media that includes movies, animations, and graphics (Ananda et al., 2023).

By declaring that the e-module was valid by validators and practical by small groups, prototype IV was produced.

Assessment Phase

The assessment process includes two crucial stages: the assessment of e-modules by teachers and students, both of which are meant to determine the feasibility of the e-modules that have been built. The results of practicality by teachers and students can be seen in Table 4.

Table 4. Practicality Analysis of Teachers and Students

Aspects	Teachers	Students	Category
Ease of Use	1.00	0.90	Practice
Time Efficiency	0.92	0.89	Practice
Benefits	0.98	0.81	Practice
Average	0.97	0.87	Practice

Practicality of E-module Based on Teacher Response Questionnaire

Chemistry teachers at SMA Negeri 6 Tanjung Jabung Barat tested the applicability of e-modules. There are three criteria evaluated: ease of use, time efficiency, and advantages. In terms of ease of use, the practical category had an average Aiken's V value of 1.00. This demonstrates that, according to the teachers, using e-modules in learning is simple and straightforward.

In terms of time efficiency, the average value of Aiken's V is 0.92, indicating a practical category. This demonstrates that the use of e-modules in learning is extremely efficient, in line with the assertion of Daryanto et al. (2014), who state that the usage of modules can increase learning efficiency.

In terms of advantages, the practical category had an average Aiken's V value of 0.98. This demonstrates that e-modules bring considerable benefits to the learning process, such as assisting the teacher's role as a facilitator. In the learning process, which is a source of learning, a teacher plays a variety of roles. They can be an assessor or evaluation, a facilitator, a guide or demonstration, a motivator, or even the so-called initiator (Yasin et al., 2023).

Overall, including the three dimensions of practicality by teachers, the average Aiken's V value is 0.97 in the practical category.

Practicality of E-module Based on Student Response Questionnaire

At this stage, the e-module practicality test was done on 28 students of class XI IPA SMA Negeri 6 Tanjung Jabung Barat. Prototype IV was tested at this point. There are three elements to consider: ease of use, time efficiency, and benefit.

The average Aiken's V rating for ease of use was 0.90, 0.89 for time efficiency, and 0.81 for benefit. Overall, the practical category had an average Aiken's V value of 0.87 out of the three elements.

It can be seen that the value of practicality by teachers is higher than the value of practicality by students. This happens because teachers have more experience in teaching and understand how teaching materials can be applied effectively in various learning situations (Tosh et al., 2020), they frequently view instructional materials from a wider angle, taking into account their capacity to meet curriculum requirements and promote long-term learning; In order to effectively use new instructional materials, teachers frequently receive extra assistance and training, which boosts their confidence and contentment with the resources (Rice et al., 2021) conversely, students may not have the same access to this support and may find new or more complex teaching materials difficult or uncomfortable (Wang et al., 2021).

E-Module Effectiveness

The goal of the e-module is to improve students' capacity for critical thinking. A test with up to eight descriptive questions was given to evaluate the development of critical thinking abilities. Test were given to the experimental and control groups both before (pre-test) and after (post-test) the lesson.

With a maximum score of 70, the pre-test scores for the two courses were comparable: 21 for the experimental class and 22 for the control class. The average score for the experimental class was 30, while the average score for the control class was 31. With a maximum score of 70, the experimental and control class post-test outcomes were 57 and 43, respectively.

The post-test socre is significantly higher than the pre-test score. This happens because Students typically receive instruction or training that greatly expands their knowledge and abilities. Research indicates, for instance, that gamified learning interventions can raise student motivation and academic accomplishment, both of which are correlated with improved post-test results (Stratton, 2019).

To determine effectiveness, the N-Gain formula was used. 0.7 of the experimental class in the fairly effective group and 0.4 of the control class in the less effective category were obtained from the N-Gain analysis. Students who employ problem-based learning and chemo-entrepreneurship-oriented acid-base e-modules have a greater N-Gain percentage compared to students who do not. This is due to Instant feedback is frequently made available by digital teaching resources, which enables students to identify and fix errors right away (Castro-Alonso et al., 2021). Table 5 displays the N-Gain analysis's findings.

Table 5. N Gain Analysis Result

Class	N-Gain	Category
Experiment	0.7	Moderately Effective
Control	0.4	Less Effective

Students' use of instructional resources created especially for problem-based learning is credited with this efficacy. Students that participate in problem-based learning must work together with other students to solve challenges, which can improve their critical thinking abilities (Pratiwi et al., 2020).

Conclusion

The designed problem-based learning-oriented chemo-entrepreneurship e-modules are found to be valid, useful, and successful in enhancing students' critical thinking skills, according to the research that has been done.

Acknowledgments
The authors would like to thank the supervisors, validators, chemistry teachers and students of class XI IPA SMA Negeri 6 Tanjung Jabung Barat who have helped in this research.

Author Contributions
Conceptualization, developing research instruments, directing research, and writing articles, H.S.P., B.O; validating of e-module, Y., A.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

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