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Development of Problem-Solving-Oriented Electronic Module (E-Module) to Improve The Critical Thinking Skills of Class XI Senior High School Students on Acid-Base Material

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ABSTRACT: The Independent Curriculum is a solution to the tight competition for human resources in the 21st century. The critical thinking skills needed in the 21st century can be improved through studying chemistry, especially acid-base materials. The problem-solving learning model is an appropriate learning model for understanding acid-base materials and can improve students' critical thinking skills. Learning media that can be used in chemistry learning are electronic modules. The aim of this research is to develop a problem-solving-oriented e-module to improve critical thinking skills in acid-base materials. The development model in this research uses the 4D model by Thiagarajan. The development of problem-solving-oriented e-modules was declared suitable for improving students' critical thinking skills in acid-base material in terms of validity, practicality, and effectiveness. Validity is seen in content and construct validity, both of which received a mode value of 5 in the very valid category. Practicality can be seen from the results of the student response questionnaire, which obtained a percentage of 98.75% in the very practical category and is supported by the results of observations of student activities. Effectiveness can be seen from the results of the students' critical thinking skills pretest and posttest, which obtained a significance value of 0.00 using the paired sample t-test.

KEYWORDS: acid-base, chemistry, critical thinking skills, e-module, problem-solving.

INTRODUCTION

Education is a very important aspect of life. Education aims to make the nation's life more intelligent. The curriculum is a tool for learning activities to realize national education goals. Based on Minister of Education and Culture Decree No. 56 of 2022, the government is making improvements to the curriculum, namely becoming an independent curriculum. The characteristics of the Independent Curriculum are that it focuses on essential material (literacy and numeracy), is more flexible, and is student-centered learning [1]. The Independent Curriculum is a solution to the very tight competition for human resources in the 21st century [2]. There are five skills that must be developed in the 21st century, namely problem-solving skills, critical thinking skills, creative thinking skills, communication skills, and collaborative skills [3]. These skills can be trained through learning science, especially chemistry. The characteristics of chemistry include three aspects, namely chemistry as a product, process, and scientific attitude. If chemistry subjects are presented as a whole, students will be produced who are skilled in higher-level thinking, one of which is critical thinking [4].

One of the chemical materials that contains facts, concepts, principles, and procedures is acid-base materials [5]. Based on the results of a pre-research interview by one of the chemistry teachers at State Senior High School 8 of Surabaya, she said that many students still had difficulty understanding acid-base material. This is supported by the results of pre-research at State Senior High School 8 of Surabaya on January 26, 2024, by taking 20 respondents, who stated that as many as 68.60% of students thought that the acid-base material was difficult because students did not understand many terms and there were many sub-materials in the acid-base material. The concept of acids and bases is a complex chemical concept [6]. Apart from that, the acid-base material emphasizes that students have direct experience with concrete or practical objects [7]. This is in accordance with the Learning Outcomes of the Independent Curriculum as stated in Minister of Education and Culture Decree No. 008 of 2022, namely that at the end of phase F, students are able to use the acid-base concept in everyday life.

Based on the characteristics of acid-base material, which is complex and requires an experiment, the use of a problem-solving learning model is the right solution so that students do not experience difficulties in understanding the material. This is because the problem-solving learning model can encourage students to discover concept independently, translate complex information, examine

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new knowledge, and be able to learn with previous knowledge [8]. Problem-solving is a procedure carried out by someone to solve problem that begins with digesting the given problem, followed by digging up the necessary facts and explanations, and then looking for a way out the problem accompanied by several considerations [9]. According to Polya in his book entitled How to Solve It, in finding a solution to a problem, there are four steps that must be taken, namely: step 1: understand the problem; step 2: device a plan; step 3: carry out the plan; and step 4: look back [10]. The steps of this problem-solving learning model have the potential to improve students' critical thinking skills [11]. This is proven by the results of previous research, which states that problem-solving learning can train students' critical thinking [12]. Based on other previous research, problem-solving learning model have a role in improving students' thingking skills [13].

Critical thinking skills are needed in studying acid-base material because acid-base material contains facts, concepts, and procedures [14]. There are six indicators of critical thinking skills involved in the critical thinking process: interpretation, analysis, evaluation, inference, explanation, and self-regulation [15]. In this study, researchers applied four indicators of critical thinking skills, namely interpretation, analysis, inference, and evaluation, because these four indicators can be applied in studying acid-base material in learning outcomes using the concept of acid-base in everyday life and adapted to problem-solving steps. Interpretation indicators can be improved by guiding students in understanding problems regarding acids and bases in life, formulating problems, and determining goals. Inference indicators can be improved by guiding students in formulating hypotheses and drawing conclusions. Analysis indicators can be improved by guiding students in creating a framework for thinking, creating observation and experiment data tables, analyzing observation and experiment data, and answering several analysis questions. Evaluation indicators can be improved by guiding students to check the answers and arguments given [16]. Facts in the field state that students' critical thinking skills are still relatively low. This is based on pre-research results that showed that as many as 51.00% of students could not answer interpretation questions, 60.00% of students could not answer inference questions, 51.00% of students could not answer analysis questions, and 59.00% of students could not answer questions. evaluation. To improve students' critical thinking skills, learning media are needed [17].

One of the learning media that can be used in chemistry learning is modules. Because the use of modules in learning can make learning more student-centered (student-centered learning), educators as facilitators no longer dominate learning [18]. As time goes by, modules can be innovated and integrated into forms of presentation in the form of electronic media (e-modules), which are flexible because they can be accessed anywhere and at any time via desktop computers, notebooks, smartphones, etc. One software that can be used to develop e-modules that are interactive, easy to use, and can combine several media, both audio and visual, is Flip PDF Professional software [19]. Based on pre-research results, it is known that as many as 57.20% of students feel the learning process is more enjoyable if they use electronic media. E-modules themselves are still rarely used in learning. This is based on the results of a pre-research interview by one of the chemistry teachers at State Senior High School 8 of Surabaya, who said that e-modules have never been used in chemistry learning, especially acid-base material. Therefore, e-modules need to be developed to improve students' critical thinking skills. In developing e-modules, a learning model is needed that can increase student activity and understanding [20]. Problem-solving is a learning model that can be oriented towards developing e-modules to increase understanding of concepts in acid-base materials [21].

Based on the explanation above, this research aims to develop a problem-solving-oriented e-module to improve critical thinking skills of class XI Senior High School students on acid-base material that are suitable for use based on validity, practicality, and effectiveness aspect.

METHOD

The research method used is research and development. Research and development is a research method used to produce products and test the effectiveness of certain products [22]. In this research, a trial was carried out on the development of problem-solving-oriented e-module learning media to improve critical thinking skills in acid-base material, guided by Thiagarajan's research and 4D model development methods, which include the define stage, design stage, develop stage, and disseminate stage [23]. However, in this research, it was only limited to the development stage. The development trial design uses the One Group Pretest Posttest Design [22]. Before students start testing the e-module, they are given a pretest sheet. The pretest is used to determine students' initial skills. Then students are given treatment, namely learning to use problem-solving-oriented e-modules. After that, students were given a posttest. The posttest contains descriptive questions to determine students' critical thinking skills as an influence from the e-module.

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The trial was carried out on class XI students at State Senior High School 8 of Surabaya, totaling 20 students, during 3 meetings over a period of 2 weeks.

Appropriateness: The modules developed are reviewed for validity, practicality, and effectiveness. The validity of the e-module in this study was measured using an instrument validation sheet containing assessments regarding content criteria and construct criteria. Construct validity includes language, presentation, and graphic criteria. Validation data was analyzed using a scoring mode based on the Likert scale in Table 1.

Table 1. Validity Categories

Score	*Category*
1	Very Less Valid
2	Less Valid
3	Fairly Valid
4	Valid
5	Very Valid

Source: Riduwan, 2015

The practicality of the e-module in this study was measured using an instrument-student response questionnaire sheet and supported using student activity observation sheets. Practicality data were analyzed by giving scores based on the Guttman scale and interpreted using the Guttman scale interpretation in Table 2.

Table 2. Percentage of Practicality

Average Score	*Criteria*
0%-20%	Very Less Practical
21%-40%	Less Practical
41%-60%	Fairly Practical
61%-80%	Practical
81%-100%	Very Practical

Source: Riduwan, 2015

Effectiveness in this research module was measured using an pretest and posttest sheet instruments for critical thinking skills. Effectiveness data from critical thinking skills tests were analyzed using SPSS, and normality testing was done using the Shapiro-Wilk technique. If the significance value is > 0.05, then the data is declared normally distributed. Then it was tested using a paired sample t-test, which was declared effective if the significance value was < 0.05 [24].

RESULT AND DISCUSSION

This research was carried out in accordance with the steps in the 4D model research and development method by Thiagarajan, which include the define stage, design stage, develop stage, and disseminate stage, which is only limited to the develop stage [23].

A. Define

This stage has the aim of establishing and defining development requirements. The define stage includes front-end analysis, student analysis, concept analysis, task analysis, and specifying instructional objectives [23]. Front-end analysis aims to surface and determine the basic problems experienced. The curriculum used is the Independent Curriculum. This is in accordance with Minister of Education and Culture Decree No. 56 of 2022 that the government is making improvements to the curriculum, namely becoming an independent curriculum. Based on the learning outcomes in the independent curriculum, acid-base material is one of the materials that must be studied. Apart from that, based on literature studies conducted, acid-base material is one of the materials in high school chemistry subjects that must be studied and understood by students because it is a basic concept for understanding other higher concepts [25]. Another basic problem is that the chemistry module used in learning at State Senior High School 8 of Surabaya only

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contains material descriptions. Student analysis is carried out to analyze the cognitive development and critical thinking skills of students. Students' cognitive development is classified as a formal operational stage that is capable of abstract thinking. Meanwhile, students' critical thinking skills are still low. Concept analysis aims to identify the concepts that will be studied and outlined in the e-module. The material discussed is acid-base theory, acid-base indicators, and acid-base strength. Task analysis aims to identify the tasks that will be carried out by students. The tasks contained in the e-module include understanding the problem, devising a plan, carrying out the plan, and looking back. Students' task are adapted to problem-solving steps by Polya to improve critical thinking skills [10]. This is based on previous research, which states that problem-solving-based learning can train critical thinking skills in acid-base materials [26].The formulation of learning objectives is used as a basis for designing e-modules.

B. Design

At the design stage, benchmark reference tests, media selection, format selection, and initial design are carried out. which are prepared based on the specifications of the learning objectives. The benchmark test created is a critical thinking skills test consisting of 19 essay questions containing 6 interpretation indicator questions, 4 inference indicator questions, 7 analysis indicator questions, and 2 evaluation indicator questions [15]. Media selection is adjusted to student analysis, task analysis, and previous concept analysis. The learning medium that will be developed in this research is a problem-solving-oriented e-module to improve students' critical thinking skills in acid-base material. The use of modules in learning can make learning more student-centered and educators as facilitators no longer dominate learning [18]. Previous research states that the development of problem solving-oriented e-modules can improve students' critical thinking skills. Then choose a format that is adapted to the general model components [27]. The module developed contains a cover, foreword, table of contents, list of images, list of tables, concept map, introduction (module identity, learning outcomes, learning objectives, flow of learning objectives, e-module description, instructions for use), material description, worksheets, and an evaluation sheet oriented towards problem-solving learning steps. Then create an initial design in the form of a problem-solving-oriented e-module draft to improve the critical thinking skills of class XI Senior High School students on acid and base material for 3 meetings. The first meeting discussed acid-base theory, the second meeting discussed acid-base indicators, and the third meeting discussed acid-base strength. The e-module cover can be seen in Figure 1.

Figure 1. E-Module Cover

C. Develop

At the development stage, e-module creation, expert assessment, and development trials are carried out. The e-module creation stage is the realization stage of a previously created plan. The result of this stage is a problem-solving-oriented e-module product on acid-base material, which can be uploaded via Flip PDF Professional. This software was chosen because the use of Flip PDF Professional has been deemed feasible. This is based on previous research, which states that the Flip PDF Professional application is suitable for

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use in schools for creating e-modules [19]. The expert assessment stage includes review and validation. The e-module was reviewed by a chemistry lecturer at Surabaya State University to get suggestions as a basis for revision. Next, validation was carried out by 2 chemistry lecturers at Surabaya State University and 1 chemistry teacher at State Senior High School 8 of Surabaya so that an e-module was produced that was suitable for testing. The trial was carried out on class XI-3 students at State Senior High School 8 of Surabaya, totaling 20 students, during 3 meetings over a period of 2 weeks.

D. Validity

The validity of the e-module is obtained from the results of expert validation in terms of content and construct validity. The e-module is said to be valid if the assessment of 3 validators, consisting of 2 chemistry lecturers at Surabaya State University and 1 chemistry teacher at State Senior High School 8 of Surabaya, reaches mode ≥ 4 [28]. The content validity results of the e-module developed obtained a mode value of 5 with a very valid category from 11 assessment aspects. Meanwhile, the construct validity results of the developed e-module obtained a mode value of 5 with a very valid category from 13 assessment aspects, which included language, presentation, and graphic criteria. This shows that the problem-solving-oriented e-module, which was developed to improve students' critical thinking skills in acid-base materials, can meet validity criteria in the very valid category. This is in accordance with previous research, which states that the development of e-modules based on problem-solving is valid in terms of content and construct validity [20].

E. Practicality

The practicality of the e-module was obtained from the results of student response questionnaires and supported by the results of observations of student activities. E-modules are said to be practical if data analysis of student response questionnaire results shows a percentage of $\geq 61\%$ using the Guttman scale and is supported by data from observations of student activities [28]. Student response questionnaires will be filled in by students after learning using e-modules developed to assess practicality. The observed student activities were adjusted to the learning steps for problem solving by Polya [10]. Apart from that, the activities of the students observed were in accordance with Facione's critical thinking skills, which included four indicators: interpretation, inference, analysis, and evaluation [15]. Student activities include obtaining information from the problem (Step 1: understood the plan, interpretation indicator), composing research questions or problem formulation (Step 2: device a plan, interpretation indicator), determining the goals to be achieved (Step 2: device a plan, interpretation indicator), making temporary answers or hypotheses to the problem (Step 2: device a plan, inference indicator), creating a thinking framework such as an experimental flow (Step 2: device a plan, analysis indicator), writing the results of observations or experiments into a table (Step 3: carry out the plan, analysis indicator), analyzing the data from the observations or experiments (Step 3: carry out the plan: analysis indicator), drawing conclusions from the problem (Step 4: look back, inference indicator), and double-checking how strong the arguments given are (Step 4: look back, evaluation indicator). Student acitivitiec can be seen in Figures 2 and 3.

Figure 2. Learning Process using E-Module

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Figure 3. Practical Acitivities in the Laboratory

The results of the response questionnaire obtained a percentage of 98.75%, which shows that the problem-solving-oriented e-module on acid and base material that was developed meets very practical criteria for improving students' critical thinking skills, supported by observations of students' activities during three meetings. This is in accordance with previous research, which states that the development of e-modules based on practical problem solving for use with student responses regarding the quality of problem-solving-based e-modules is included in the very good category so that it can stimulate students' thinking abilities in solving problems [20].

F. Effectiveness

The effectiveness of the e-module is obtained from the results of the pretest and posttest of students' critical thinking skills. The test used contains 4 indicators of critical thingking skills by Polya, namely interpretation, inference, analysis, and evaluation [15]. The e-module is said to be effective if there is a significant difference when measured using paired sample t-test analysis. Before carrying out the paired sample t-test, it is necessary to carry out a normality test. The normality test in this study used the Shapiro-Wilk technique. If the significance value is > 0.05, then the data is declared normally distributed. If the data is normal, it can be continued with the paired sample t-test. If the significance value is < 0.05, it can be said that there is a significant difference between the students' pretest and posttest results after using the developed e-module [24]. Data on pretest and posttest results can be seen in Figure 4.

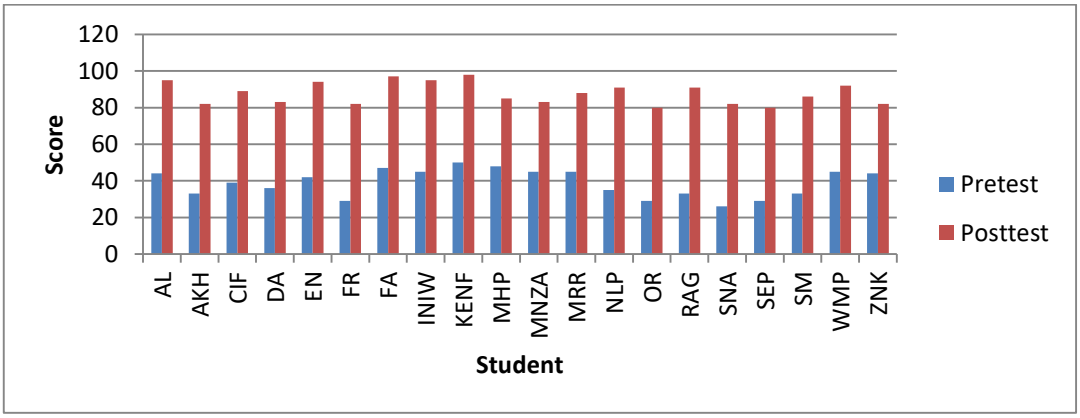

Figure 4. Pretest and Posttest Value Data

Based on Figure 4, It can be seen that there is an increase in pretest and posttest results. Overall, students got low scores on the pretest because the acid-base material had not been given and critical thinking skills had not been trained. Meanwhile, during the

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posttest, overall scores increased because students have been trained in critical thinking skills using problem-solving-oriented e-modules. The indicator of critical thinking skills trained in e-module developed is interpretation, inference, analysis, and evaluation In line with this, the results of previous research stated that the problem-solving chemistry module was effective in improving students' critical thinking skills by increasing pretest and posttest scores [29].
Then the pretest and posttest data were analyzed using SPSS. The results of the normality test can be seen in Figure 5.

Tests of Normality						
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistics	Df	Sig.	Statistics	Df	Sig.
pretest	,204	20	,029	,914	20	,075
posttest	,186	20	,069	,911	20	,067

Figure 5. Tests of Normality

Based on the Shapiro-Wilk normality test analysis, the critical thinking skills pretest shows a significance value of 0.075. Meanwhile, the critical thinking skills posttest showed a significance value of 0.067. This shows that the pretest and posttest critical thinking skills are normally distributed because the significance value is > 0.05. Because the data is normally distributed, it can be continued with the paired sample t-test. The results of the paired sample t-test can be seen in Figure 6.

Paired Samples Test								
	Paired Differences					T	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 pretest - posttest	-48.90000	5.91964	1.32367	-51.67048	-46.12952	-36,943	19	,000

Figure 6. Paired Sample t-Test

Based on the analysis of the paired sample t-test in Figure 6, a significance value of 0.00 was obtained.This shows that problem-solving-oriented e-modules can be said to be effective in improving students' critical thinking skills in acid-base material because the significance value obtained is < 0.05. This is in accordance with previous research, which states that the problem-solving learning model is effective in improving thinking skills in chemistry learning [30]. This is also supported by previous research that the development of e-modules based on problem-solving is effectively used in chemistry learning [20].

CONCLUSION

Based on the results of the research conducted, it can be concluded that problem-solving-oriented e-modules are suitable for use to improve students' critical thinking skills in terms of validity, practicality, and effectiveness. Validity is seen in content and construct validity, both of which received a mode value of 5 in the very valid category. Practicality can be seen from the results of the response questionnaire, which obtained a percentage of 98.75% in the very practical category and is supported by the results of observations of student activities. Effectiveness can be seen from the results of the students' critical thinking skills test, which obtained a significance value of 0.00 using the paired sample t-test.

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