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The Development of Virtual Laboratory-based STEM Approach Equipped Feedback to Improve Critical Thinking Skills on Acid-Base Concept

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ABSTRACT
The purpose of this research is to produce development products of virtual laboratory media with a STEM approach and equipped with appropriate feedback to be applied in learning and the opportunity to improve critical thinking skills on acid-base concepts. This research consisted of (1) analysis (needs analysis and front-end analysis), (2) design, and (3) development. The research instrument used consisted of interview questionnaires, media feasibility validation sheets, material feasibility, concept validity, and readability test questionnaires. Media and subject matter experts who are involved are a teacher, a lecturer, and 33 students as respondents to test readability. While The results showed that the product virtual labs application, user guide, and a feedback book has a percentage of 89 % for feasibility media, 85% for the feasibility of the material, and 100% for the truth of a concept that can be in the category is very feasible. The media readability test by students obtained a percentage result of 81 % with a very good category. Therefore, this virtual laboratory is very feasible to be applied in learning activities and has the opportunity to improve students' critical thinking skills on the acid-base concept. Recommended future research can apply this product in classroom learning.

Keywords: *Virtual laboratory, STEM, Feedback, Critical thinking skill.*

1. INTRODUCTION

The 2013 curriculum prepares students to be able to understand science and technology, think logically, critically in solving various problems in real life [1]. It is important for students to understand the concept of acid-base because its application is often encountered in real life [2]. Acid and base, one of the materials in science that is learned through practicum and lecture method [3]. But in practice, practicum on the acid-base concept is not maximized especially because of time constraints and the availability of lab equipment is still inadequate [4]. Interviews that were conducted with science teachers at JHS 10 Malang showed that the COVID 19 pandemic caused the acid-base practicum to not be carried out which was then only accommodated through learning videos. Learning videos still have weaknesses, including communication only takes place in one direction so that feedback cannot occur [5]. However, The results of observations at JHS UNESA 2 Surabaya in 2017 show that 70% of students understanding of acids, bases, and salts has not reached the KKM because the use of learning media does not involve activities and is less able to improve students understanding of concepts so that practicum is considered very important because students can understand the theory by proving the process through laboratory activities [6][7].

The acid-base characteristic concept is often found in the environment so that the student is stressed to be able to solve the problems that this can be accomplished through thinking skills in the study of the acid-base concept [8]. Especially now, we are in the 21st-century which demands that education must be able to produce students who have character, creative, competitive, and critical thinking [9]. Critical thinking skills involve activity to think deeply and logically and are known identical to the individuals' ability in analyzing facts, organizing ideas, defending their opinions required in a decision dealing with the problem, and were able providing conclusions to correlate the concepts learned by experiments [10]. To achieve this, according to Ennis there are several indicators including simple clarification, building basic skills, concluding, making further explanations, as well as strategies and tactics [11]. However, the PISA survey shows that Indonesia is ranked 70th out of 78 countries in 2018 [12]. The results of the study stated that students' critical thinking on the acid-base concept was still relatively low [13]. This is supported by the results of observations carried out at JHS 10 Malang, that students' critical thinking skills are

still relatively low on the concept of acids and bases. Through practical activities, it can encourage students to understand a concept independently so the students' critical thinking skills can be improved [14]. Various studies have been carried out to improve students' critical thinking skills. Research on media Prezi-based learning can improve student's critical thinking skills [16]. However, previously developed teaching media, haven't accommodated the practical needs of the acid-base concept, which can be overcome by the development of the virtual laboratory. The research by Lutfi regarding implementation of the virtual laboratory on the optical material effect on the ability to think critically, with a percentage of 53.14% observed data and the results of *post-test* of 47.06% [17]. The virtual laboratory that has been developed has not provided students with an understanding of the application of science and technology in solving problems. This can be overcome through a STEM approach. In addition, there is a lack of reciprocal relationships between teachers and students which can be overcome with feedback to improve the quality of the learning [18]. However, studies that have developed virtual laboratory media that apply the STEM approach and feedback to improve critical thinking skills are still rarely done.

A virtual laboratory is a medium of learning in the form of an application that simulates practical activities like real experiments [19-20] that consist of a presentation of information, the simulation program, the operation of the tool, and the reference [21]. Virtual labs provide solutions to the limitations of laboratory facilities and introduce students to technology and innovation [22]. Generally learning with the help of virtual simulation media can provide the opportunity to repeat the wrong experiment, deepen the experience independently, and provide an interactive virtual environment [23] so can improve students' critical thinking skill [24]. Science learning in the current era needs to be an association of technology to solve the problems through science product is associated with STEM approach. STEM approach was formed by the interdisciplinary of several disciplines among science, technology, engineering, and mathematics can require the involvement of students in applying science and technology to the problems [25], so that students can apply their activities of planning, constructing, and utilizing technology so that students' affective, cognitive, and psychomotor aspects can be involved [26]. Acid-base concept is often encountered in daily, so it's appropriate to design STEM activities that provide creativity, curiosity, and inquiry for students [27] Beers stated that The STEM approach has the advantage because it involves 21st-century skills, namely "4C" which includes creativity, collaboration, communication, and critical thinking that can be presented through virtual media [28-29]. Learning by using the media can take place through the communication that occurs after the reaction of feedback [30]. Feedback is given as a form of information or student performance evaluation [31].

Feedback leads to the analysis and improvement of knowledge of one of ability to think critically [32]. A virtual laboratory is a medium simulation that can provide feedback on information access carried out by users [33].

Based on this framework, a virtual laboratory media was developed by applying the STEM approach and equipped with feedback on the acid-base concept. The virtual laboratory media presents practical acid-base concept activities by applying the STEM approach and feedback so that students can be actively involved in investigating a problem that can improve students' critical thinking skills, especially on the acid-base concept. The purpose of this research is to develop a virtual laboratory media with a STEM approach that is equipped with valid and appropriate feedback in improving students' critical thinking skills on the acid-base concept.

2. METHODS

The research method applied in this research is the research and development method (Research and Development). The research design adopts the ADDIE development model according to Lee and Owens which is devoted to developing multimedia and is arranged procedurally and systematically in producing media development products [34]. The ADDIE model consists of 5 stages including: analysis, design, development, implementation, evaluation. The research was only carried out at the development stage due to time and cost constraints [35].

The first stage is conducting a needs analysis through interviews with science teachers at SMP 10 Malang and literature studies that aim to determine the implementation of learning and the obstacles faced. Then carried out front-end analysis consisting of student analysis to determine the characteristics of learning and cognitive abilities. The second stage is the design stage, namely designing storyboards and materials that will be inputted in the virtual laboratory media. Next, the development stage is carried out, namely developing the design into a product that is suitable in terms of material content, appearance, ease of use so that it is feasible to be applied in learning. At the development stage to test the feasibility of the product by taking the study participants in whom a lecturer of Education Science Universitas Negeri Malang and a science teacher at SMPN 10 Malang as validator matter experts and media as well as 33 students of SMP N 10 Malang as a user.

The instruments used in the product validity/feasibility test consisted of interview questionnaires, media feasibility validation questionnaires, material feasibility validation questionnaires, and concept correctness, as well as readability test questionnaires for students. The instrument is based on a Likert scale [36], while the

concept of truth instrument is based on the Guttman scale [37]. Data collection techniques were carried out through interviews, and questionnaires. While the results are obtained from product development consist of quantitative data and qualitative data. Quantitative data was obtained from the results of the product feasibility score assessment results by lecturer and teacher, product readability test results by students, and qualitative data in the form of written suggestions and /or comments from both validators and students. Based on the feasibility test, research data will be obtained which will be used as material for product improvement before being implemented.

The data that has been collected is then analyzed using the average analysis technique so that the percentage of eligibility is obtained based on the following formula:

$$P = \frac{\sum Xi}{\sum X} x\ 100\%$$

Description:
P = Percentage of eligibility
$\sum Xi$ = Total gain score
$\sum X$= Total maximum score [38].

The data obtained from the results of the percentage of feasible level, the next converted based product assessment criteria percentage in Table 1 [39]:

Table 1. Product feasibility assessment criteria

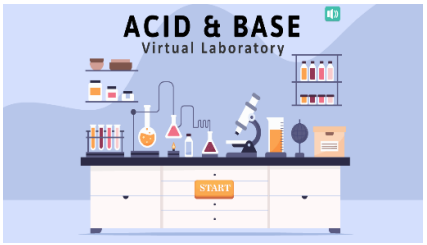
Percentage	Category
X> 80%	Very good/ very feasible
60%<X≤80%	Good/feasible
40%<X≤60%	Good enough/ feasible enough
20%<X≤40%	Not good/not feasible
X≤ 20%	Very not good/ very less feasible

The percentage obtained will show the level of the impropriety of products that have been developed. Products can be said feasible when percentage eligibility has reached 61% with good category/feasible. While qualitative data will be analysed based on validation test data and readability test on virtual laboratory media products obtained based on comments and suggestions from material validators and media validators as well as suggestions from respondents or in this case students.

3. RESULTS AND DISCUSSION

This research resulted in the virtual product development laboratory media that have consisted of media applications, an instruction manual, and a book discussion practicum. The virtual laboratory media is developed in the form of an android-based application that students can use to do practical. The practicum is displayed according to the STEM approach which is then obtained feedback at the end of the activity.

The virtual laboratory media contains several components including the front page (loading the media title), the submit page, the main menu, instructions for use, student practicum activities, and evaluation tests to test the level of students' critical thinking skills. Simulation activity experiments students who presented consists of the manufacture of soap and identification of acids and bases. On the front page, there is a media title of " Acid-base Virtual Laboratory " which can be seen in Figure 1.



(a)

(b)

Figure 1 (a) Virtual laboratory cover screen (b) Virtual laboratory main menu.

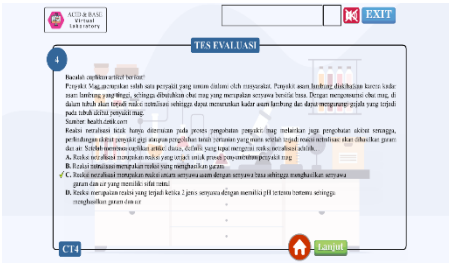
The Figure 1a is the front-page view of the virtual laboratory media. The virtual laboratory media contains some two (2) lab simulations presented in the main menu in the Figure 1b. The practicum displays several features including material, case studies, preparation, simulation, and ends with a worksheet.

The first experiment activity is a soap-making practicum simulation. At the beginning of the activity, students were presented with several questions related to material that could encourage students' critical thinking skills on simple explanation indicators. Then presented cases originating from problems in everyday life related to the concept of acid-base for further identification. In STEM learning, students are required to be involved and solve real-world problems [40]. Activities to find information and choose the right solution to overcome these problems can encourage students to carry out

strategies and tactics. At the practicum preparation stage, students choose material tools that are suitable for the product to be made at the next stage. Then at the practicum stage students make a product based on the materials and procedures that have been selected. The process of identifying problems, finding and choosing solutions, making a product in this soap-making simulation is an activity that applies the STEM approach in the engineering aspect. Then the technology aspect can be seen based on the product in the form of soap produced at the final stage of the activity. STEM learning seeks to build awareness to students of the importance of caring for daily problems that surround them through problem solving practices [28]. In addition, there are mathematic aspects that can be seen when students determine the amount of material needed in making the product.

The second experiment activity is the identification of acid and base using several indicators. Acids and bases are a representation of STEM approach aspects of science. Before carrying out practical activities, students are presented with material on acid-base indicators. In accordance with the stages in the science aspect, at the beginning of the activity, students write down the definition of the indicator. These activities can encourage students to think critically on aspects of simple explanations. Furthermore, students are directed to formulate problems and formulate hypotheses where can encourage students to think critically on indicators of building simple skills and managing strategies and tactics. In the next stage, namely the preparation stage, students choose the material tools that will be used in the practicum to identify the pH of an acid-base solution. The observations obtained are then written in an observation table. Determining the pH level of a solution using indicators and writing data in tabular form is the application of STEM in the mathematic aspect. The last stage is to write the discussion and conclusions from the observations that have been made. So those students are encouraged to be able to think critically on aspects of providing further explanations and concluding. Khoiriyah mentioned that problem solving, decision making, analyzing, investigating, and evaluating activities are aspects of critical thinking that can be given to students through STEM learning that can be integrated into multimedia [41].

In every learning activity carried out, students get feedback. Feedback in this case is a form of motivation for students. The feedback features presented consist of giving awards, approvals, strengthening achievements, disapproval, improvement plans, or further performance planning [42]. In addition, to evaluate student performance, at the end of the activity there is an evaluation test according to the acid-base concept. The evaluation test is prepared based on critical thinking indicators to maximize the improvement of students' critical thinking skills which can be seen from Figure 2.



(a)

(b)

Figure 2 (a) Evaluation Test (b) Score display.

Figure 2a is a display of questions presented in accordance with critical thinking indicators. Besides that, the evaluation test is equipped with corrective feedback which is presented in the form of scores and discussion of questions that can be seen from Figure 2b. In accordance with the benefits of virtual laboratory media that can be used independently outside the classroom, the feedback feature can help students to control and assess their difficulties, progress, [18] and quality of their learning activities especially on indicators of conceptual clarity and coherence focus [43]. In addition, it can be seen the reason for the incorrect answer completely [44].

The product feasibility test consists of a media and material feasibility test conducted by a lecturer in the Science Education Study Program, State University of Malang and a science teacher at SMPN 10 Malang as media and material experts. Based on the feasibility test media obtained quantitative data in the form of results percentage average presented in Table 2.

Table 2. Average percentage of the virtual laboratory media feasibility test

No	Assessment Aspect	Average	Eligibility Percentage (%)	Criteria
1	Media Design and Display	0.866	86.6	Very feasible
2	Grammar	0.813	81.3	Very feasible

3	Sound system	0.875	87.5	Very feasible
4	Ease of use	1.00	100	Very feasible
5	Media Effectiveness	0.875	87.5	Very feasible
	Average value of feasibility	**0.89**	**89**	**Very feasible**

Based on these results, the virtual laboratory media obtained an average percentage of 89 %. So, it can be stated that the media is very feasible to use. The percentage obtained is not maximal in the grammatical aspect. However, the virtual laboratory media still has shortcomings in several aspects that can be seen based on the results of qualitative data from the feasibility of the media. Qualitative data obtained by comments and suggestions validators who among them is the "color of the white paper does not contrast with the grey background contrast making it difficult to read" and "write source under the picture taken". Based on the suggestions made improvements presented in Figure 3:

(a)

(b)

Figure 3. (a) before revision (b) after revision

Figure 3a is a virtual laboratory media before repairs are made. While Figure 3b is a virtual laboratory media after consideration of revisions to change the background and add the appropriate source images used below.

Then the feasibility of the material presented in the virtual laboratory media can be known based on the results of the feasibility test of the material and the truth of the concept. Due diligence material that consists of several aspects of the assessments presented in Table 3:

Table 3. Average percentage of the virtual laboratory material feasibility test.

No	Assessment Aspect	Average	Eligibility Percentage (%)	Criteria
1	The suitable of the material with learning indicator	0.84	84	Very Feasible
2	Experiment presentation	0.87	87	Very Feasible
3	Material presentation	0.91	91	Very Feasible
4	Presentation of Evaluation Test	0.84	84	Very Feasible
5	The suitability of the media with STEM approach and feedback	0.85	85	Very Feasible
6	The suitability of the media as a medium for independent learning	0.88	88	Very Feasible
7	The suitability of the media with critical thinking indicators	0.75	75	Feasible
	Average value of feasibility	**0.85**	**85**	**Very Feasible**

Based on the results of the material feasibility test, quantitative data was obtained in the form of an average percentage score of 85 % with very feasible criteria. The gain is still not maximized on the suitability of the media to the indicators of critical thinking. However, based on the material feasibility test, the virtual laboratory media obtained very feasible criteria. Then based on the acquisition of qualitative data that “a major improvement is needed in the layout. As for the concept, it is stated that it is feasible. It’s just that a lot of writing symbols and units that are not in accordance with the standard rules”. However, the results of the assessment of the truth test of the concept obtained an average score of 100% so that it can be said that the virtual laboratory media can be applied in learning the concept of acid and base.

The media readability test was carried out on 33 students of SMP N 10 Malang who had taken the acid-base material. Based on the media readability test, an average percentage of 81 % was obtained with very good criteria. The qualitative data was taken from the suggestions and comments of students which included "the use of acid-base virtual laboratory media can make it easier for students to learn because the language presented is not complicated and easy to understand. Hopefully in the future, the virtual acid-base laboratory media can be known more widely by many people". Simulation media supports students in training and constructing their understanding of concepts independently [45]. However, in some aspects the score is still not optimal, including students still have difficulty understanding the evaluation test questions and the linguistic aspect which according to students is still complicated because many activities must be carried out.

Based on the media feasibility test and the readability test for students, virtual laboratory media with a STEM approach equipped with feedback is feasible to be applied as an effort to improve critical thinking skills. This is in accordance with research conducted by Pramuji that interactive multimedia with a STEM approach can improve the STEM approach [46]. The research was also conducted by Parno that virtual simulation with PBL-STEM approach can improve critical thinking skills [24]. ICT- based STEM learning is considered efficient to be used to explain materials as well as active learning and provide learning outcomes understanding of the concept to students [47]. Truchly states that virtual laboratory multimedia can engage students in STEM fields and help them to understand difficulties [48]. Through problem-solving, decision making, evaluation, and investigative activities, the STEM approach is useful in developing critical thinking skills [49]. Besides, critical thinking skills can be trained through the provision of feedback [50]. The application of written feedback during learning is able to motivate students to improve their performance, so that critical thinking skills can be improved [51].

4. CONCLUSION

Based on the results of research and development of media virtual laboratory approach STEM equipped with feedback on the acid-base concept, it can be concluded that (1) the media lab is categorized as very feasible in the feasibility test media with a percentage average of 89 %, (2) virtual laboratory media is categorized as very feasible in the material feasibility test with an average percentage of 85% and 100% in the concept truth test. In addition, based on the readability test, a very decent category was obtained with an average percentage score of 81 %. Thus, the development of virtual laboratory media with a STEM approach equipped with feedback could improve students' critical thinking skills on acid-base concepts. Recommendations for further research can be tested on the effectiveness of the product in the learning process in the classroom.

AUTHORS' CONTRIBUTIONS

All authors conceived and designed this study. All authors contributed to the process of revising the manuscript, and at the end all authors have approved the final version of this manuscript.

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