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## The Virtual Laboratory Based on Problem Based Learning to Improve Students' Critical Thinking Skills

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**Abstract:** The ability to think critically is a basic competency that must be possessed by students. This study aims to determine the level of critical thinking skills of junior high school students in Bima Regency, West Nusa Tenggara, Indonesia. Various studies have been carried out that explain how important students' critical thinking skills are, but there have not been too many studies on efforts to develop and empower students' critical thinking skills in a practical way. In this thesis, we introduce the technique of empowering students' critical thinking skills by developing a virtual laboratory media based on problem based learning on the material of the human excretory system. In this development, use software construct2 to develop a device which is then integrated with a problem based learning model. It is proven that a virtual laboratory based on problem based learning can improve the critical thinking skills of junior high school students in Belo Kaputen Bima District. We hope that the development of PBL-based virtual laboratory media can improve dramatically, such as the use of 3-dimensional and 4-dimensional software to improve students' understanding of critical and constructive thinking without losing quality.

**Keywords:** *Critical thinking skills, media development, problem based learning, software construct2, virtual laboratory.*

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### Introduction

In schools must be able to grow the character of students to have the ability to think critically, creatively, communicatively, and collaborate to be able to compete in the 21st century (Fridanianti et al., 2018). 21st century competencies can be described as follows: (a) Ways of thinking: Creativity and innovation, critical thinking, problem-solving, decision making, and learning to learn; (b) Ways to work: Communicate and cooperate; (c) Tools for work: General knowledge and skills of information and communication technology; (d) Way of living: career, personal and social responsibility including cultural awareness and competence (Roni et al., 2012).

The demands of science learning in the 21st century are aimed at preparing students with various skills and abilities such as creativity, innovation, critical thinking, problem-solving, communication. Collaboration, Information and Communications Technology Literacy (ICT Literacy), and leadership (National Science Teachers Association, 2003). Critical thinking ability is a competency that must be possessed by students, critical thinking skills have been proven to prepare students to think in various disciplines because critical thinking is a cognitive activity that is carried out cooperatively in determining and making decisions (Rahman, 2018). Critical thinking skills are also part of providing superior human resources to face the industrial revolution 4.0 and society 5.0. Critical thinking is a potential that everyone has, this ability can be measured, trained, and developed to be better than before (Sulistiani & Masrukan, 2016). Critical thinking consists of six aspects of cognitive skills, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2011).

One of the factors causing the low critical thinking ability of students in using conventional learning methods such as lectures is still being accommodated by the teacher. Traditional learning models like this cannot hone and develop students' critical thinking skills (Shodiqin et al., 2021). One of the learning models that can develop critical thinking skills is the problem-based learning model. PBL is considered suitable for developing students' critical thinking skills

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because this learning model trains and emphasizes students to be actively involved, Problem-based learning improves problem-solving skills, critical and creative skills, improved learning outcomes, communication skills, teamwork, adaptation of new knowledge, and self-evaluation (Ong et al., 2020).

An alternative solution is the development of learning media in the form of a Virtual Laboratory based on problem-based learning (Haq & Suryadarma, 2019). Learning with interactive media containing animations or videos that can be used as teaching materials and presentations in distance learning activities can help students to improve conceptual understanding. The implementation of problem-based virtual laboratory media can improve student learning achievement which can be seen from the N-Gain Score (Panggabean et al., 2019). In addition, the use of media in the form of a virtual laboratory can improve students' understanding of concepts (Salam et al., 2010).

The use of construct 2 software in the COVID-19 situation is considered to be an alternative as a form of interpretation of new learning style patterns or Transformative Learning. The use of software in the form of construct 2 is very helpful for students and teachers in understanding complex learning concepts (Saputra et al., 2021). Therefore, researchers are interested in researching with the title "Development of Problem Based Learning-Based Virtual Laboratory Media to Improve Critical Thinking Skills for Junior High School Students".

## Literature Review

### *Science Learning*

The purpose of education is to lead students to changes in behavior both intellectually, morally, and socially so that they can live independently as individuals and social beings (Widyatiningtyas, 2002). The nature of science is built on aspects of scientific products, scientific processes, scientific attitudes, and applications (Minister of Education and Culture of The Republic of Indonesia, 2020). The knowledge possessed by individuals is basically in the form of concepts obtained from interactions with the environment. This concept is then developed and compiled into principles that can be used as a basis for thinking (Sardinah et al., 2012).

### *Problem Based Learning Model*

Problem-based learning is a series of learning activities that emphasize the process of solving problems faced scientifically. The problem-based learning model emphasizes student curiosity (Suhirman et al., 2021). PBL is active learning with a student-centered approach and focuses on skills, lifelong learning, the ability to apply knowledge, and skills in problem-solving (Khoiri, 2013). The use of the PBL model is proven to be much better with conventional learning (Darhim et al., 2020). PBL can also improve critical thinking skills (Kardoyo et al., 2020). In addition to improving critical thinking skills, PBL can also improve speaking and communication skills (Dwi Swandari et al., 2013).

### *Virtual Laboratory*

To improve the quality of learning, it is necessary to have supportive learning instruments such as virtual laboratory instruments (Pei, 2021). VLab is designed as a supporting tool for Biology/Science learning (Muhamad et al., 2012). Virtual laboratories can also be used as good learning in the world of education (Hernandez et al., 2006). Learning with a virtual laboratory orientation has advantages such as being portable, learning can be done anytime and anywhere because it is equipped with software according to user mobility. In addition, the virtual laboratory is also accessible, meaning that it is easily accessible (Manikowati & Iskandar, 2018). The Utilization of virtual laboratories has a significant impact in terms of preparing students for real experiences, saving costs for procurement and maintenance of tools and materials, the flexibility of location, study time, and practice (Muhajarah & Sulthon, 2020). A virtual laboratory is considered quite feasible as a learning medium and of very good quality (Arista & Kuswanto, 2018).

### *Construct2 Software*

Virtual laboratory-developed based on HTML5 and developed using construct2. Thus, this application can support several platforms at once such as PC and Android as long as the platform supports HTML5. Construct 2 can be used as an interactive media or virtual laboratory because of its strong search capabilities, mobile and e-learning computerization, support for effective performance-based learning (Saputra et al., 2021). This software is also considered effective in online-based learning (Salam et al., 2010).

### *Critical Thinking Skills*

Critical thinking consists of six aspects of cognitive skills, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation or self-regulation (Facione, 2011). The following is the syntax of critical thinking skills. Students' critical thinking skills can be empowered by using appropriate learning media. The selection of good learning media can improve student learning outcomes and critical thinking skills (Susilowati et al., 2018).

## Methodology

### *Research Design*

This type of research is research and development (R&D). research design flow refers to R&D research with modifications that are aligned with the aims and concepts of the research. Sugiyono's R&D research steps are; identification of potentials and problems, data collection, data development, product design 1, design evaluation. Design revision, product design 2, limited scale test, product revision 2, wide-scale trial, product revision 3, final product.

### *Research Samples and Sampling Methods*

This research was conducted at two schools in Bima district, West Nusa Tenggara province consisting of SMP Negeri 1 Woha involving 335 students, while SMP Negeri 2 Belo involved 134 students. Each school used 2 classes as the experimental class and the control class. The instrument validation involved 9 experts in their field consisting of 2 media experts, 3 material experts, 2 linguists, 2 practitioners/teachers.

### *Data Collection Instrument*

Media feasibility assessment data by media experts and the substance of the material obtained by providing a questionnaire containing an assessment of the virtual laboratory learning media. Data on teacher and student responses to virtual laboratory learning media were obtained from student and teacher reflection questionnaires at the end of the lesson. Data on the evaluation results of student practicum simulations after using the virtual laboratory were obtained from student and teacher questionnaires at the end of the lesson. Learning media in the form of Syllabus, Learning Implementation Plan (RPP), virtual laboratory applications, Student Activity Sheets (LKPD).

### *Data Analysis*

The data obtained in the study were analyzed by 3 tests, namely the validity test, feasibility test, and descriptive statistical test. The validity test was carried out to determine the validity of the instrument by testing the validity of the Aiken's. index. The feasibility test of the virtual laboratory media was carried out with the Paired Sample T-Test assisted by SPSS. Pair test the effectiveness of the virtual laboratory media was carried out using a descriptive statistical test with the help of SPSS. The research instrument before being used was tested for reliability, difficulty, and discriminating power with the help of SPSS. Reliability test to see the consistency of the data before and before using the pbl-based virtual laboratory, while the difficulty and discrepancy test to see the level of difficulty of the questions (easy, medium, difficult) and the difference between the two classes in each school.

## Findings/Results

### *The Validation Stage of The Virtual Laboratory Media Based on Problem Based Learning*

In the validation stage, the researcher used 3 media validators, 3 material validators, 2 language validators, and 2 from science learning practitioners/teachers. The total number of v validators used in media development is 9 experts in their respective fields. Assessment of learning media by media experts with a range of values using 4 categories of Likert scale scoring. Aspects assessed include: 1) the effectiveness of product efficiency; 2) maintainable; 3) usability; 4) compatibility; 5) reusable; 6) creativity, communicative, simple, and attractive; 7) audio (narration, sound effects, back sound, music; 8) visual (layout design, typography, back sound). The validator team at the material validation stage is he who has a doctorate and master degree who is a computer expert or an expert in learning media development design. In the first stage of product development, suggestions and input from media experts are used as a reference for the revision of learning media. The following are the results of the virtual laboratory media validation based on problem-based learning.

Table 1. Recapitulation of media validation in the development of a problem-based learning virtual laboratory.

No.	Rated Aspect	Aikens' Validity Calculation		
		$\Sigma S$	V	Note
1.	Effectiveness and efficiency	22	81%	Valid
2.	Maintenance	21	78%	Valid
3.	Usability	21	78%	Valid
4.	Compatibility	24	89%	Valid
5.	Reusable	22	81%	Valid
6.	Communicative	22	81%	Valid
7.	Creative in ideas and pouring ideas	23	85%	Valid
8.	Audio (narration, sound effects, back sound, music)	23	85%	Valid
9.	Visual (layout design, typography, color)	23	85%	Valid
10.	Motion media (animation)	23	85%	Valid
11.	Interactive layouts	21	78%	Valid
12.	Simple and attractive	22	81%	Valid

Assessment of learning media by media experts with a range of values using 4 categories of Likert scale scoring. Aspects assessed include: 1) aspects of the truth of content and concepts, 2) depth of material, 3) actualization of material, 4) systematic and logical presentation of relevance, 5) material according to student needs, 6) material is presented in a simple, coherent way. The validator team at the material validation stage is him who has a doctoral degree and a master's degree who is a biologist on excretory system material. In the first stage of product development, suggestions and input from media experts are used as a reference for media revision in the context of the coverage of the material. The results of the revision are then used as a second assessment. The following are the results of material validation by material experts.

Table 2. Recapitulation of the validation of problem-based learning-based virtual laboratory development materials

No.	Rated Aspect	Aikens' Validity Calculation		
		$\Sigma S$	V	Note
1.	Clarity of learning objectives	24	89%	Valid
2.	Relevance of learning objectives with KI/KD/curriculum	21	78%	Valid
3.	The suitability of the material with the learning objectives	22	81%	Valid
4.	The accuracy of using a problem-based learning model	23	85%	Valid
5.	Interactivity	23	85%	Valid
6.	Giving the motivation to learn	21	78%	Valid
7.	Contextuality and actuality	21	78%	Valid
8.	Material depth	23	85%	Valid
9.	Easy to understand	23	85%	Valid
10.	Systematic / coherent / clear logic flow	22	81%	Valid
11.	Clarity of descriptions, discussions, examples, simulations, and exercises	23	85%	Valid
12.	Consistency of evaluation with learning objectives	23	85%	Valid
13.	Content/concept truth	22	81%	Valid
14.	Material depth	23	85%	Valid
15.	Material update	21	78%	Valid
16.	Systematic presentation of logical and relevant	22	81%	Valid
17.	Material according to student needs	21	78%	Valid
18.	Image/animation/video selection accuracy	24	89%	Valid
19.	The material presented is simple and easy to understand	23	85%	Valid
20.	The material is presented in a coherent manner	22	81%	Valid

Language validation is carried out to ensure the use of language that is following the Big Indonesian Dictionary (KBBI) on virtual laboratory products, research instruments, and student activity sheets (LKPD). This is done to support and minimize the use of non-standard and informal language. Language validation is carried out by 2 Indonesian language education lecturers who are experts in their fields.

Table 3. Recapitulation of language validation in the development of a problem-based learning virtual laboratory

No.	Rated Aspect	Aikens' Validity Calculation		
		$\Sigma S$	V	Note
1.	The writing is legible	22	81%	Valid
2.	The language used is simple and easy to understand	23	85%	Valid
3.	Language is communicative	21	78%	Valid
4.	Simple sentences, containing information, right on target	21	78%	Valid
5.	The writing is legible	22	81%	Valid
6.	The language used is simple and easy to understand	21	78%	Valid
7.	Language is standard and formal	21	78%	Valid

Suggestions and inputs from validators and teachers are used as a basic reference for the improvement of problem-based learning-based virtual laboratory media. Sharing input and suggestions is very useful for the progress and development of learning media so that it is suitable for use as learning media that can empower students' critical thinking skills.

#### Reliability

Reliability is the constancy or consistency of the instrument being measured. The results of the research instrument reliability testing are presented as follows:

Table 4. Reliability Test Results Development of a virtual laboratory based on problem-based learning

No.	School/ Institution	SPSS Assisted Reliability Test (Cronbach's Alpha)	
		Limited Scale	Wide-Scale
1.	SMP Negeri 1 Woha	0.437	0.901
2.	SMP Negeri 2 Belo	0.982	0.851

#### Level of Difficulty and Power Difference

The results of the analysis of the level of difficulty and differentiating power are assisted by SPSS. The following are the results of the recapitulation of the level of difficulty and differentiating power of the questions, which are as follows:

Table 5. The Results of The Difficulty and Differentiating Power of The Virtual Laboratory Media Based on Problem Based Learning

No.	Mean	Difficulty Level	Discrimination Power	Explanation
1.	0.66	moderate	0.456	very good
2.	0.28	difficult	0.619	very good
3.	0.44	moderate	0.508	very good
4.	0.53	moderate	0.390	pretty good
5.	0.75	easy	0.557	very good
6.	0.41	moderate	0.262	pretty good
7.	0.66	moderate	0.550	very good
8.	0.25	difficult	-0.076	bad
9.	0.66	moderate	0.271	pretty good
10.	0.44	moderate	0.541	very good
11.	0.81	easy	0.491	very good
12.	0.22	difficult	0.404	very good
13.	0.66	moderate	-0.283	Bad
14.	0.59	moderate	0.446	very good
15.	0.41	moderate	0.642	very good
16.	0.41	moderate	0.523	very good
17.	0.47	moderate	0.687	very good
18.	0.44	moderate	0.588	very good
19.	0.41	moderate	0.891	very good
20.	0.22	difficult	0.590	very good
21.	0.41	moderate	0.344	pretty good
22.	0.25	difficult	-0.025	Bad
23.	0.47	moderate	0.225	pretty good
24.	0.22	difficult	0.484	very good
25.	0.22	difficult	0.590	very good

Table 5 shows that there are 7 questions in the difficult category, 16 questions in the medium category, and 3 questions in the easy category. The question instrument shows that item numbers 8, 13, 22 are classified as bad, so they are not used as an instrument for critical thinking skills.

#### *Test The Feasibility of The Virtual Laboratory Media Based on Problem Based Learning*

The product trial on a limited scale was carried out on 15 students of SMP N 1 Woha and 1 science teacher, while SMP N 2 Belo involved 15 students and 1 science teacher. This limited test data is to determine the feasibility of the media by determining the value of the N-Gain Score, as well as the level of effectiveness of the virtual laboratory media through teacher and student response questionnaires.

#### *Feasibility Test Paired Sample T-Test*

The results of the trial were limited to the feasibility level of the virtual laboratory media based on the N-Gain Score at SMP 1 WOHA, namely 42.67% in the control class, 81.07% in the experimental class. This proves that the problem-based learning-based virtual laboratory media is categorized as feasible. Meanwhile, at SMP N 2 BELO, the N-Gain Score for the control class was 21.87% and the experimental class was around 75.20%. The use of problem-based learning-based virtual laboratory media in both schools is categorized as feasible.

*Table 6. The Results of The Paired Sample T-Test with A Limited Scale*

School Name	Treatment	N-Gain Score		Sig. (2 tailed)	Correlation	Explanation
		Pretest	PostTest			
SMP N 1 Woha	Experiment	45.75 %	87 %	.000	0.372	Worthy
	control	34.06 %	69.21 %	.000	0.766	Decent Enough
SMP N 2 Belo	Experiment	26.47 %	80.82 %	.000	0.641	Worthy
	control	22 %	66.38 %	.000	0.572	Decent Enough

Questionnaires were distributed to students and teachers and then the average percentage obtained was calculated. The results of the feasibility calculation on student responses ranged from 82.64% while teacher responses ranged from 75.5%. The following are the results of the recapitulation of the results of student and teacher responses at the level of feasibility in each aspect of the limited scale test.

*Table 7. The Results of The Recapitulation of Student Responses*

No.	Indicator	Percentage (%)			
		Limited Scale	Explanation	Wide-Scale	Explanation
1.	Software engineering aspects	77.5 %	Worthy	80.67 %	Very Worthy
2.	Learning design aspects	75 %	Worthy	82.17 %	Very Worthy
3.	Visual communication aspect	77.5 %	Worthy	82.33 %	Very Worthy
4.	Concept truth aspect	75 %	Worthy	84.72 %	Very Worthy
5.	Readability aspect	75 %	Worthy	75 %	Very Worthy
	<b>Average Percentage</b>	<b>75.5 %</b>	<b>Layak</b>	<b>82.64%</b>	<b>Very Worthy</b>

#### *Test The Effectiveness of Media with Descriptive Statistics*

The results of the statistical descriptive test assisted by SPSS by determining the level of effectiveness of the virtual laboratory media based on problem-based learning obtained 98% in SMP N 1 WOHA and 97% in SMP N 2 BELO. This shows that the developed media can be categorized as Effectively used in learning the excretory system material.

*Table 8. Results Of Limited-Scale Statistical Descriptive Test*

No.	School Name	N	Min	Max	Mean	Std. deviation
1.	SMP N 1 Woha	15	97.00	104.00	99.80	2.00713
2.	SMP N 2 Belo	15	94.00	107.00	99.80	3.38484

Based on the results of the analysis using SPSS on a limited scale test, the Cronbach's Alpha value of 0.734 showed that the questionnaire used in the study was reliable, while the value of Cronbach's Alpha in the Broad-scale trial ranges from 0.630. This shows that the questionnaire distributed in both schools has a high level of reliability. The following are the results of the large-scale and large-scale reliability tests.

*Wide-Scale Trial (Feasibility Test Paired Sample T-Test)*

The results of a large-scale trial on the feasibility level of virtual laboratory media based on the N-Gain Score at SMP 1 WOHA are 69.21% in the control class, 87.00% in the experimental class. This prove that the problem-based learning-based virtual laboratory media is categorized as feasible. Meanwhile, at SMPN 2 BELO, the N-Gain Score for the control class was 66.38% and the experimental class was around 80.82%. This proves that the use of problem-based learning-based virtual laboratory media in both schools is categorized as feasible.

*Table 9. The Results of the Wide-Scale Paired Sample T-Test*

School Name	Treatment	N-Gain Score		Explanation
		Pretest	PostTest	
SMP N 1 Woha	Experiment	45.75 %	87 %	Worthy
	control	34.06 %	69.21 %	Decent Enough
SMP N 2 Belo	Experiment	26.47 %	80.82 %	Worthy
	control	22 %	66.38 %	Decent Enough

Based on the results of the questionnaire analysis on the teacher's responses to the large scale test, it can be concluded that the virtual laboratory media is said to be feasible with an average percentage ranging from 80.37% with a very feasible category. Meanwhile, based on the results of student responses ranging from 82. 61% with a very decent category.

*Table 10. Recapitulation of Teacher Responses to Virtual Laboratory*

No.	Indicator	Percentage (%)			
		Limited Scale	Explanation	Wide-Scale	Explanation
1.	Software engineering aspects	82.5 %	Very Worthy	80.61 %	Very Worthy
2.	Learning design aspects	83.93 %	Very worthy	81.69 %	Very Worthy
3.	Visual communication aspect	78.75 %	Worthy	82.54. %	Very Worthy
4.	Concept truth aspect	78.75 %	Worthy	81.47 %	Very Worthy
5.	Readability aspect	78.12 %	Worthy	84.03 %	Very Worthy
	<b>Average Percentage</b>	<b>80.37 %</b>	<b>Very Worthy</b>	<b>82.07 %</b>	<b>Very Worthy</b>

*Test Effectiveness with Descriptive Statistics*

The results of the statistical descriptive test by determining the level of effectiveness of the virtual laboratory media based on problem-based learning obtained 98% in SMP N 1 WOHA and 97% in SMP N 2 BELO. This shows that the developed media can be categorized as Effectively used in learning the excretory system material.

*Table 11. Results of Broad-Scale Statistical Descriptive Test*

No.	School name	N	Min	Max	Mean	Std. deviation
1.	SMP N 1 Woha	32	72.00	114.00	98.00	10.59215
2.	SMP N 2 Belo	34	67.00	116.00	97.91	9.80837

The large-scale trial aims to determine the level of effectiveness of the virtual laboratory media based on problem-based learning and the benefits of the media for students and teachers in the learning process. The results of the final product revision are suitable for use because they have gone through the validation test phase by experts, educational practitioner tests, limited-scale field trials, large-scale field trials, and improvements from suggestions and input from experts, students, and teachers. In the trial scale students and teachers did not provide suggestions and improvements because the product developed was said to be feasible for use on a large scale. The results of the questionnaire at each stage of the trial were used as the basis for determining the quality of the virtual laboratory media based on problem-based learning and making improvements based on the suggestions and inputs obtained.

**Discussion***Results of the Stages of Development of Problem Based Learning Virtual Laboratory Media*

The media is developed based on preliminary studies, namely literature studies, and field studies. The results of the preliminary study are used as the basic basis in developing virtual laboratory media which of course has gone through the validity stage by experts. The biggest investment in education is to develop computer-based media such as virtual laboratories that can support physical laboratories and are proven to be efficient, flexible, and have great benefits both in the world of education (Novitra et al., 2020). Educational innovations such as online platforms can educate students.

The use of online platforms such as virtual laboratories and e-learning is needed to overcome problems and shortcomings during learning during the COVID-19 pandemic (Abumalloh et al., 2021).

The results of the preliminary study were carried out by finding out about the conditions and learning situations in the field through observation, interviews, and distributing a questionnaire on the potential and problems that exist in the field. Analysis of learning needs must look at several aspects including aspects of design, selection, and use of media in the form of abstract images that represent concepts, objectives, conditions, facilities, and time provided for learning needs (Swandi et al., 2015). Observations are made during the process of teaching and learning activities take place.

The results of observations made show that in the learning process the teacher still focuses on the lecture method and student-centered discussion. Lack of teaching aids such as learning media, adequate handbooks, and less than optimal use of laboratories. Therefore, a new alternative is needed as a form of resolution or grand design to fulfill aspects of learning-oriented learning styles that accommodate 21st century learning or transformative learning. In addition, the selection of learning models also has a large impact on the level of learning conductivity. The selection of learning models that are suitable for class conditions can also affect learning outcomes. The problem-based learning model is considered as a learning model that can empower students' critical thinking skills.

Learning media is one of the important aspects of supporting learning. Appropriate learning media will create ideal, effective, interactive, and efficient learning conditions, therefore good media is a media that is integrated into the 2013 curriculum. The selection of media and learning models can affect the level of students' critical thinking skills. Media has a great contribution to the educational and social realm, a learning environment with virtual media integrates information, communication, collaboration, learning, and management (Madouni, 2020). The availability of laboratory resources is limited and not always available, so to support learning activities that require practice, the virtual laboratory application is considered the best solution that can meet the needs of science education and its practical needs and requirements (Alneyadi, 2019).

Virtual laboratory media is a new learning style orientation that is popular in the 21st century. In addition, the COVID-19 condition emphasizes us to run online-based learning. A virtual laboratory is a series of computer programs that can visualize abstract phenomena or complex experiments carried out in real laboratories to develop critical thinking skills (Swandi et al., 2015). This is in line with the demands of 21st century learning which includes critical thinking and problem-solving skills, communication skills, creativity and innovation, and collaboration. Critical thinking ability is considered the most important skill to help students think logically, make decisions and solve problems in class (Amin et al., 2020). The use of virtual laboratory media in some science materials has been used, but the excretory system material is still very lacking. Therefore, researchers take advantage of the conditions and potential problems that exist in the school environment to create a virtual laboratory learning media based on problem-based learning. The use of construct 2 software in the covid-19 situation is considered to be an alternative as a form of interpretation of new learning style patterns (Transformative Learning). The use of virtual-based media has significant supremacy of higher performance fiber over conventional learning. implementation of problem-based virtual laboratory media can improve student achievement seen from the percentage of N-Gain Score (Panggabean et al., 2019). Interactive media for virtual laboratories with computers can save practicum costs, besides that this media can be used to develop students' critical thinking skills (Sakti et al., 2012). In developing a Web-Based learning platform, it must provide flexible access to classifying learning conditions and conditions (Gorgon et al., 2020).

Problem-based learning-based virtual laboratory media that have gone through the validity test stage by experts are said to be feasible to be tested in the field with a feasibility percentage ranging from 82% Media Validity, 83% Material Validity, and 83% Language Validity. The average overall aspect ranges from 82% with a decent category, so that modules that have passed the validation stage can be used as learning media. The data obtained from expert judgments were analyzed using coding, then described qualitatively and depicted the data on a continuum to determine the category of assessment. Then calculate the validity of the Content Validity Ratio and Content Validity Index (Swandi et al., 2015). Meanwhile, according to (Adi & Iqbal, 1999) The virtual laboratory developed can be said to be feasible if it has met the assessment aspects by media, material, language, teacher, and student experts.

The product trial phase is carried out by distributing learning media in the form of a virtual laboratory based on problem-based learning that has been converted into an application (APK) that supports android and computers. At the product testing stage, there are 2 stages, namely the limited-scale trial stage and the broad-scale trial stage. At this stage, a questionnaire was also distributed to determine the level of feasibility and effectiveness of the product. The questionnaire distributed is a student and teacher response questionnaire to problem-based learning-based virtual laboratory media. The results of the questionnaire at the trial stage are used as the basic basis for making improvements to the developed media by the suggestions and inputs obtained.

The virtual laboratory media that was developed has the aim of improving students' critical thinking skills because critical thinking skills can improve student learning outcomes from the previous both in cognitive, psychomotor, and affective aspects. Students' critical thinking skills were measured before and after receiving learning treatment using a virtual laboratory based on problem-based learning which was calculated using the Paired Sample T-Test. The results of the paired sample T-Test obtained results of 87% for SMP 1 Woha and 80.82% for SMP N 2 Belo in the High category.



This shows that the level of critical thinking skills of students in both schools is relatively high. The use of problem-based learning models can empower students' critical thinking skills which can be seen in student learning outcomes (Darhim et al., 2020). Problem-based learning combined with character emphasis can empower students' critical thinking skills and curiosity but is not significant for students' naturalist intelligence (Suhirman et al., 2021).

#### *Eligibility of Virtual Laboratory Media Based on Problem-Based Learning*

The results of a large-scale trial in a virtual laboratory based on the N-Gain Score at SMPN 1 WOHA, namely 69.21% in the control class, 87.00% in the experimental class. This proves that the problem-based learning-based virtual laboratory media is categorized as feasible. Meanwhile, at SMP N 2 BELO, the N-Gain Score for the control class was 66.38% and the experimental class was around 80.82%. This proves that the use of problem-based learning-based virtual laboratory media in both schools is categorized as feasible. The following is a graph of the acquisition of the feasibility level on a limited-scale and wide-scale trial based on teacher and student responses.

The results of the teacher's response questionnaire analysis were on the limited-scale test of 75.50%, and the wide-scale test of 80.37%. This shows that the learning media has a high significance value with a very good level of media feasibility. The media developed must at least be valid, practical, and effective to improve students critical thinking skills based on evaluation results, suggestions, and input from validators, and test subjects as users or practitioners (Supriyatno et al., 2020). Therefore, the learning media in the form of a virtual laboratory that has been developed can be used in learning the excretory system in humans. While the significance value obtained based on the results of the questionnaire analysis of student responses on the limited scale test ranged from 82.64% and the limited scale ranged from 82.07% with a very good category. Learning interventions using virtual laboratories have a higher level of achievement than using traditional laboratories (Sotomayor-Moriano et al., 2020). Simulations with virtual laboratories are an effective supplement for learning activities that can be used by teachers as laboratory technicians (Ong et al., 2020).

The results of the correlation test between the pretest and posttest variables at SMP N 1 Woha. The Posttest variable shows that the correlation coefficient is Sig.  $0.372 > 0.05$  probability with a significance value (Sig.) of 0.036, it can be said that there is no relationship between the pretest and posttest variables. Meanwhile, in SMP 2 Belo, it showed that the Posttest variable showed a correlation coefficient of Sig. The probability is  $0.641 > 0.05$  with a significance value (Sig.) of 0.000, so it can be said that there is no relationship between the pretest and posttest variables.

The results of the analysis of the paired-sample t-test show that the value of Sig. (2 Tailed) of  $0.000 < 0.05$  then  $H_0$  is rejected and  $H_a$  is accepted. There is an average difference between the results of the Pretest and Posttest, meaning that there is a significant effect on the use of a virtual laboratory based on problem-based learning on students' critical thinking skills at SMP 1 Woha and SMP 2 Belo. The new transition to the information age has focused on problem-solving and decision-making processes (Septiani et al., 2020).

#### *Effectiveness of Media Virtual Laboratory Based on Problem Based Learning*

Effectiveness is a product skill with a predetermined size and standard of product achievement. The effectiveness test was carried out on students with problem-based behavior using virtual laboratory media. 32 students serve as the Experiment class at SMP 1 Woha, while SMP 2 Belo consists of 34 students. The results of the questionnaire analysis show that the virtual laboratory media is feasible and efficient to be used as an alternative in teaching the excretory system material.

PBL based virtual laboratory media is an interactive media that programs computers with virtual laboratories integrated with PBL models. The developed media is adapted to the problem-based learning syntax. The purpose of developing this product is to train students' critical thinking skills in the learning process. Interactive multimedia development aims to support problem-solving skills (Gunawan et al., 2020). Meanwhile, critical thinking skills are an important component that students must have to support 21st century learning. Critical thinking has at least six aspects of cognitive abilities, namely interpretation skills, analytical skills, evaluation abilities, inference abilities, explaining abilities, and self-regulation abilities (Facione, 2011)

The virtual laboratory media effectiveness test was analyzed using descriptive statistical analysis assisted by SPSS to obtain the level of media reliability. Before the reliability test, the previous data had met the validity test. The results of the analysis show that the level of reliability on a limited scale test with Cronbach's Alpha value is around 0.734. It means that the value of  $r_{\text{Count}} > r_{\text{Table}}$  with a significance of 5%, which is  $0.734 > 0.176$  so that the data can be said to be reliable or reliable and consistent. Meanwhile, the wide-scale test ranges from 0.630 which indicates that  $0.630 > 0.176$ , meaning that the questionnaires distributed to both schools, both on a limited and wide scale, are considered reliable or consistent. The mean value obtained is around 99.8 with the standard deviation for SMP 1 WOHA being around 2,001, and for SMP 2 BELO is 3,385. The following is a recapitulation result of the statistical descriptive test of the effectiveness of virtual laboratory media on a limited scale and wide-scale test.

The results of the virtual laboratory media reliability test on a limited and wide-scale in both schools have a high-reliability value of  $> 0.176$ , meaning that the data is considered reliable and consistent. The calculation of the reliability of the instrument was carried out to test the constancy of the research. Reliability is related to the problem of accuracy and consistency of test instruments (Kahar, 2017). The results of the analysis of item difficulty and discriminating power showed a good interpretation, where the questions developed were 25 questions that had a high level of difficulty with 7 categories of questions in the difficult, 16 questions in the medium and 3 questions in the easy. The question instrument shows that the sola items number 8, 13, 22 are classified as bad, so they are not used as an instrument for students' critical thinking and cognitive abilities. Some aspects that affect the difficulty of the questions include the lack of understanding and experience of students to solve problems. There are 3 questions in the bad category for the identification of discriminatory power. Media with a high level of feasibility can be used as a means of supporting learning (Alispahic & Alispahic, 2021)

The aspect of critical thinking skills is supported in 21st-century learning. The results of the analysis of critical thinking skills based on the acquisition of the N-Gain Score, namely at SMP 1 Woha 0.76 and at SMP 2 Belo ranging from 0.75. So it can be categorized as high. The most prominent students' critical thinking skills are in the analysis, evaluation, and explanation sections. The analysis is the ability to identify the true intentions and conclusions between arguments, questions, concepts, make decisions, gather information, and express opinions. Evaluation is the ability to judge the credibility of a statement or other interpretation by assessing one's perceptions, experiences, situations, and beliefs with definite analogies. While the explanation is a person's ability to state the results of the consideration process, the ability to justify that a reason is based on evidence, methodology, concept, or a certainly reasonable criterion, and the ability to present reasons in the form of convincing arguments (Facione, 2011).

### **Conclusion**

The characteristics of the PBL-based virtual laboratory media on the excretory system material developed by the researcher have 6 stages according to the problem-based learning syntax, besides that the developed media is integrated with cognitive aspects of critical thinking skills. The virtual laboratory media based on problem-based learning is validated by material, media, language, and practitioner expert validators. The average percentage of the feasibility of virtual laboratory media is around 82.64% which is included in the very good category. Therefore, problem-based learning virtual laboratory media is feasible to be used as a learning medium for the excretory system material. Learning tools using virtual laboratory media are considered effective to improve students' critical thinking skills on excretory system material, both for SMP N Woha and SMP 2 Belo. The results of the analysis show that the level of reliability on a limited scale test with Cronbach's Alpha value is around 0.734. It means that the value of  $r_{\text{Count}} > r_{\text{Table}}$  with a significance of 5%, which is  $0.734 > 0.176$  so that the data can be said to be reliable or reliable and consistent. While the wide-scale test ranges from 0.630 which indicates that  $0.630 > 0.176$ , meaning that the questionnaires or questionnaires distributed to both schools on a limited or wide-scale are considered reliable or consistent. The mean value obtained is around 99.8 with the standard deviation for SMP 1 WOHA being around 2.001, and for SMP 2 BELO it is around 3.385.

### **Recommendation**

Researchers who wish to conduct similar research are expected to choose other research concepts and designs that are more effective and efficient. Another model recommended by researchers is the inquiry-based learning model. The use of 3-dimensional-based software, as well as increasing the number of samples to get a strong level of data accuracy so that the level of media effectiveness is obtained which is like being used as a permanent learning medium.

### **Limitations**

This study is limited to the excretory system in humans to measure critical thinking skills in Bima district, West Nusa Tenggara. Another limitation of this study is that the number of respondents in this study can be taken on a district or provincial scale to obtain objective data.

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## Authorship Contribution Statement

Noris: Conceptualizing research, designing, designing, collecting data, analyzing data, and compiling manuscripts.  
Sulistyo Saputro: Revise the data, guide, and revise the manuscript. Muzazzinah: Revise the data, and revise the manuscript.

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