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Development STEM-Based Biotechnology Learning Tools to Practice Critical Thinking

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ABSTRACT

This study aims to describe the validity of learning tools in terms of several aspects such as content, language, and presentation. The method used in this research is to use a modified 4D (Define, Design, and Development), model and implemented in the Postgraduate Program for Science Education, State University of Surabaya. The data collection technique was carried out by the validation method. The assessment instrument uses a validation sheet. The tools developed are in the form of lesson plans, Student worksheet, and critical thinking ability tests. The validity of this STEM-based biotechnology learning tool is based on content feasibility, language feasibility, and presentation feasibility. Validity of STEM-based biotechnology learning tools were assessed by three validators consisting of two biology lecturers and one biology teacher. Data analysis was carried out quantitatively. The results of the validation of STEM-based biotechnology learning devices by three validators obtained an average score of 3.83 lesson plans, 3.67 Student worksheet, and 3.67 critical thinking ability test with a very valid category. Based on data analysis, it can be concluded that the learning tools developed are valid and suitable for use in learning

INTRODUCTION

In 21st century education, the national education system faces very complex challenges in preparing for the challenges of the quality of human resources (HR) that are able to compete in the global era. This can be achieved by preparing various activity-based learning models that are in accordance with the competencies and learning materials. The skills needed by students are critical thinking, communicative, collaborative, and critical thinking skills. Education is an effort to develop an individual's ability to live optimally as a member of society or as an individual. A quality education system in terms of process is if the learning process takes place effectively and students experience a meaningful learning process. Education essentially cannot be separated from human life because with education humans can be efficient and independent. Learning in schools itself has a goal related to improving the quality of human resources. The 20th of 2013 Article three states that national education functions to develop the ability to build dignified national character and civilization in the context of educating the nation's life which aims to develop the potential of students so that humans who believe and fear God Almighty. one, noble, healthy, knowledgeable, capable, able to solve problems, critical, independent, and become a democratic and responsible citizen (Sunhaji, 2014).

Science is a subject related to finding out about nature systematically, so that science is not only mastering a collection of knowledge in the form of facts, concepts, or principles but also a process of discovery (Depdiknas, 2016). In general, science is not

liked because it is considered difficult by students so that it can affect the development of science learning. This is known from the results of the 2020 Progamne for International Student Assessment (PISA) study in the science performance category, which shows that Indonesia has only been able to rank 70 out of 78 countries. This can be related to students' critical thinking patterns, if it refers to the PISA results. Students' thinking skills tend to be low, which can be caused by a lack of thinking skills training. Students tend to depend on teachers and textbooks as the only source of learning from the many sources of learning.

Critical thinking is a systematic and active cognitive process in assessing arguments, assessing a reality, assessing the wealth and relationship of two or more objects and providing evidence to accept or reject a statement (Rifaatul, 2015). Changes in the learning approach are one of the efforts commonly used to train students' critical thinking. Critical thinking skills can be developed using a Science, Technology, Engineering, and Mathematical (STEM) approach The STEM approach is one approach that applies problem-solving-based learning that intentionally includes scientific investigations and the application of mathematics in the context of technology design as a form of problem solving (Torlakson, 2014). STEM learning is to prepare students who are able to think scientifically and are able to utilize technology to face the future (English & King, 2015). STEM-based learning tools are structured to design activities that will be carried out during the learning process, so that learning is truly not teacher-centered. Students are expected to be critical and bolder in solving problems that are in accordance with 21st century skills that students must possess, including (1) Critical Thinking and Problem Solving, (2) Creativity and Innovation, (3) Communication, (4) Collaboration (Wahyuni, 2012).

This is supported by several studies conducted by Cooper et al., (2013) in this study which said that the learning strategies commonly used to arouse students' interest in STEM disciplines are learning strategies that involve students in problem solving experiences. The second study conducted by Suwarma et al. (2015) argues that STEM-based science learning can increase student stimulus and be critical of students when learning science. STEM-based science learning also has an impact on student learning outcomes. According to Firman (2016), explaining that STEM-based chemistry learning is learning the subject matter of chemistry which is based on system designs and the use of technology for solving real problems. Biotechnology is one material that is considered difficult to understand because it discusses the application of a complex environment. Biotechnology is a science that covers a wide range of different applications from the very simple and traditional, such as the production of beer, wine and cheese, to very complex molecular processes, such as the use of recombinant DNA (Dewi, 2016). Technologies for producing new drugs or for introducing new properties into commercial plants and animals. Biotechnology affects the efficiency of all areas involving the life sciences, and it is now realistically accepted that by the beginning of the twenty-first century biotechnology will contribute trillions of pounds to the world market (Thieman & Palladino, 2014).

Seeing the potential and existing problems, it is necessary to have a learning device that can accommodate material that optimizes the potential that exists in schools. STEM-based biotechnology learning tools are expected to be a solution to accommodate this potential, to support the learning process to improve students' critical thinking skills. In this study, the problem that became the focus was the validation analysis of

the developed device, namely the development of STEM-based biotechnology devices to train the critical thinking skills of junior high school students.

RESEARCH METHOD

General Background

This research is quantitative descriptive. Before the tool was validated by experts, the tool was first designed using a 4D model (Define, Design, and Development), adapted from Thiagarajan et al., (1974) in Ibrahim (2002). The application of this method follow 4 stages of develompment define, design, and develop.

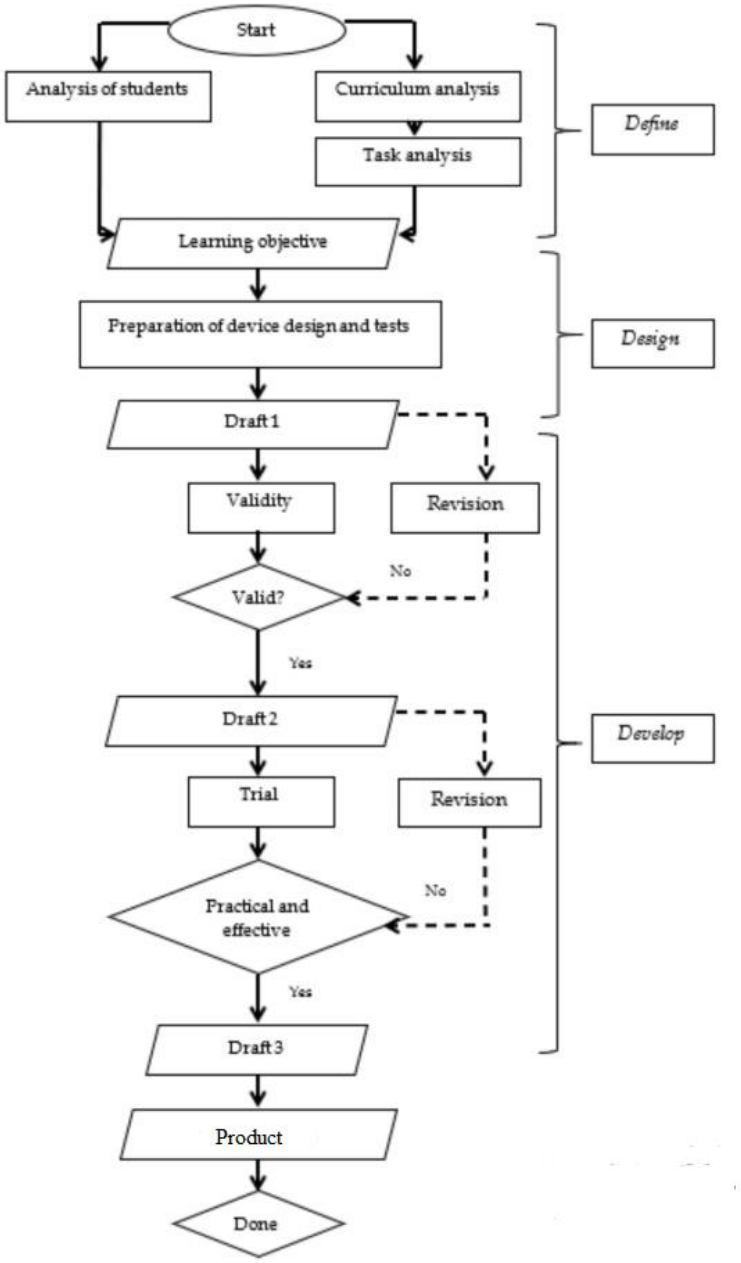

Figure1. 4-D develompent model (Ibrahim, 2002).

Sample/Participants/Group

The tools developed include: lesson plans, worksheets, and learning outcomes tests. The device is then developed and then reviewed and validated by expert lecturers. The

validation process is carried out by three validators, namely two lecturers and one teacher.

Instrument and Procedure

The research instrument is a tool used to collect data, in this study the instrument used is a learning device validation sheet. This validation sheet used to validate the developed device. Eligibility of a device learning can be measured from the quality of the device itself, where this quality can be is known if a device is validated by an expert using a validation sheet. The validation sheet contains instructions and requests to the validator for suggestions improvement and provide an assessment. The validation sheet is equipped with a choice of scores 1-4 with category score 4 is very good. A learning device can be said to be valid if the value of minimum validity is 2.51 with good predicate. The learning tools developed were reviewed by 3 validators. The tools developed include: lesson plans, worksheets, and critical thinking skills tests. Learning tools developed later Instruments and Procedures Device validation is done through validation designers, subject matter experts, focused teachers in the process of making and testing the content validation of the device made.

Data Analysis

The data from the validation of learning devices obtained from three experts were analyzed descriptively and qualitatively. The formula used to determine the level of validity on each criterion of learning devices that have been developed. The four score criteria presented are obtained based on the results of the analysis, in Table 1.

Table 1. Categorization criteria for assessment of learning device validation.

Scoring Interval	Skoring Category
3.26 - 4.00	Very Valid
2.51 - 3.25	Valid
1.76 - 2.50	Quite valid
1.00 - 1.75	Less Valid

(Riduwan, 2013).

All learning tools that have been developed and assessed for validity are then continued by calculating the percentage of reliability. The percentage of agreement is used in calculating the reliability of the instrument.

$$\textit{Percentage of Agreement} = \left(1 - \frac{A - B}{A + B}\right) \times 100\%$$

Information:

R : Reliability

A : The frequency aspect of the behavior level observed by the observer who gives a high frequency

B : The frequency aspect of the behavior level observed by the observer who gives a low frequency

An instrument is said to be good if it has a reliability coefficient greater than or equal to 0.75 or 75%. Instrument data were also analyzed using descriptive statistics with the

help of SPSS 23 software, namely the rough equation of the agreement index to get the instrument reliability coefficient, and the Cronbach alpha equation to get the instrument item reliability coefficient. The Cronbach index equation is as follows.

$$IKK = \frac{n}{N}$$

Information :
IKK = Coarse fit index
n = the same number of codes or answers
N = number of objects observed
The instrument is said to be reliable if the IKK > substantial > 0.06 in accordance

RESULTS AND DISCUSSION

Lesson Plan

The learning implementation plan is one of the important tools in the learning component and is provided by the teacher before the lesson takes place (Kemendibud, 2014). The lesson plans contain plans for face-to-face activities at several meetings. In this study, developing STEM-based biotechnology lesson plans to train students' critical thinking skills, as for the validation results that have been carried out by the validator according to the Table 2.

Table 2. Lesson plan validation results.

No.	Aspects	Rating Score			Average	Category
		Validator 1	Validator 2	Validator 3		
1	Identity Lesson Plan	4.00	4.00	4.00	4.00	Very Valid
2	Formulation of Learning Objectives	4.00	4.00	4.00	4.00	Very Valid
3	Language	4.00	3.00	4.00	3.67	Very Valid
4	Time	4.00	4.00	3.00	3.67	Very Valid
Validation Average Score					**3.83**	**Very Valid**

Table 3. Corellation r counting devices lesson plans.

Category Aspects	R_{Count}	R_{Table} (5%)	Category
Identity Lesson Plan	0.99	0.97	Valid
Formulation of Learning Objectives	0.99	0.97	Valid
Language	0.98	0.97	Valid
Time	0.99	0.97	Valid
Average	**0.99**	**0.97**	**Valid**

Table 4. Lesson plan reliability test results.

Cronbach's Alpha	N of Items
.974	15

The validation results listed in Table 2 show the average score of the validity results carried out by the three validators of 3.83. In addition, the analysis of the validity and reliability of the research instrument based on the validator's assessment was also analyzed using SPSS software. Based on the results of the analysis using the correlation

coefficient (r), the average result of Rcount obtained a score of 0.99. Based on Table 3. it is known that the value of Cronbach's Alpha in reliable statistics obtained a score of 0.974 or 97.4%. The validity of completeness of identity, formulation of learning objectives, language, and time is said to be reliable if Cronbach's Alpha value > 0.6. In the calculation above, it is known that the Cronbach's Alpha value is 0.974 > 0.6, so it is said to be reliable. This is in accordance with (Akbar, 2013) which states that good validation must include several criteria which include: a logical formulation of learning objectives, clearly presented learning materials, coherent organization, varied learning resources, clear learning activities, and step accuracy. Learning with goals, as well as assessment instruments that are clear and in accordance with objectives. Based on the results of the validation of the lesson plans that were developed, the criteria results were almost perfect, so it can be concluded that the developed lesson plans have very valid and reliable criteria, so that the lesson plans are suitable to be used as guidelines in learning activities. Likewise, the results of research by Yuniati (2018), Nabila & Mareta (2017), and Habibah et al. (2017) reveal that the use of learning tools is included in the good category based on score validation for lesson plans.

Student Activity Sheet

This student worksheet is a means of learning activities that can help facilitate understanding of the subject being studied (Prastowo, 2015). Student worksheet generally contains instructions and steps to complete a task as well as clear basic competencies to be achieved. In this study, researchers developed STEM-based biotechnology worksheets to train students' critical thinking skills, while the descriptions of the developed worksheets (Figure 2 and Figure 3).

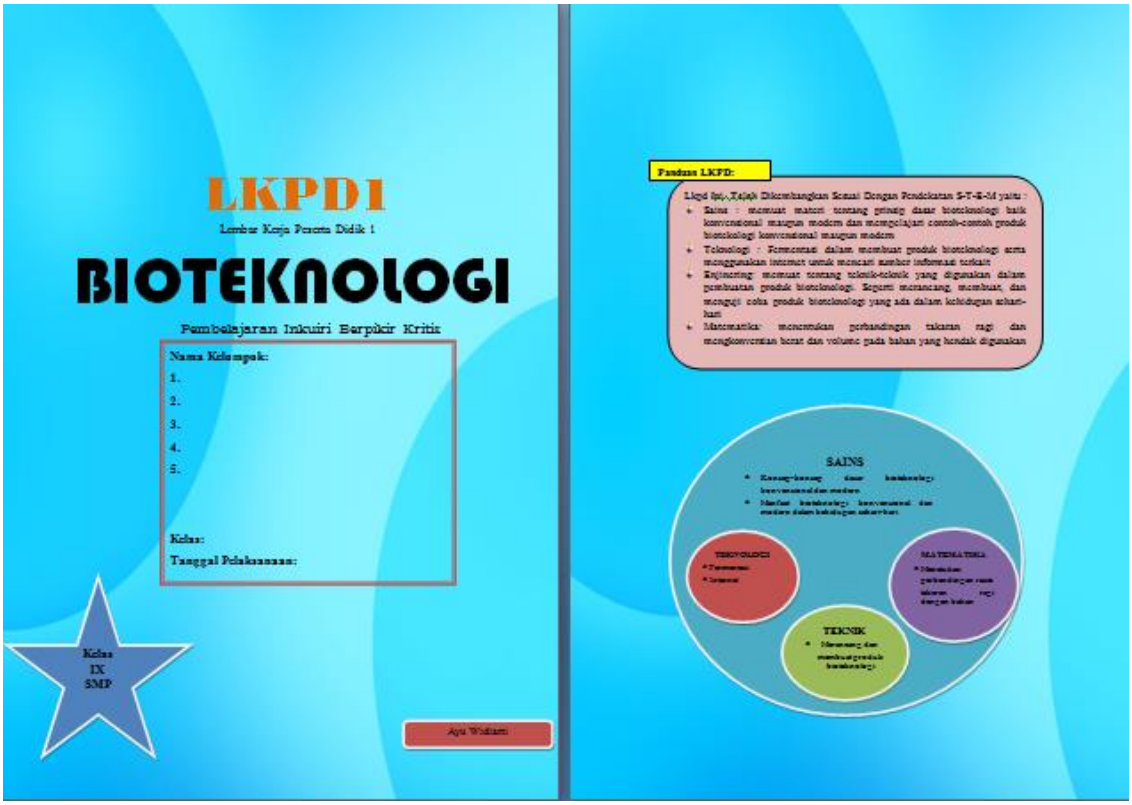

Figure 2. Display of STEM-based biotechnology student worksheet.

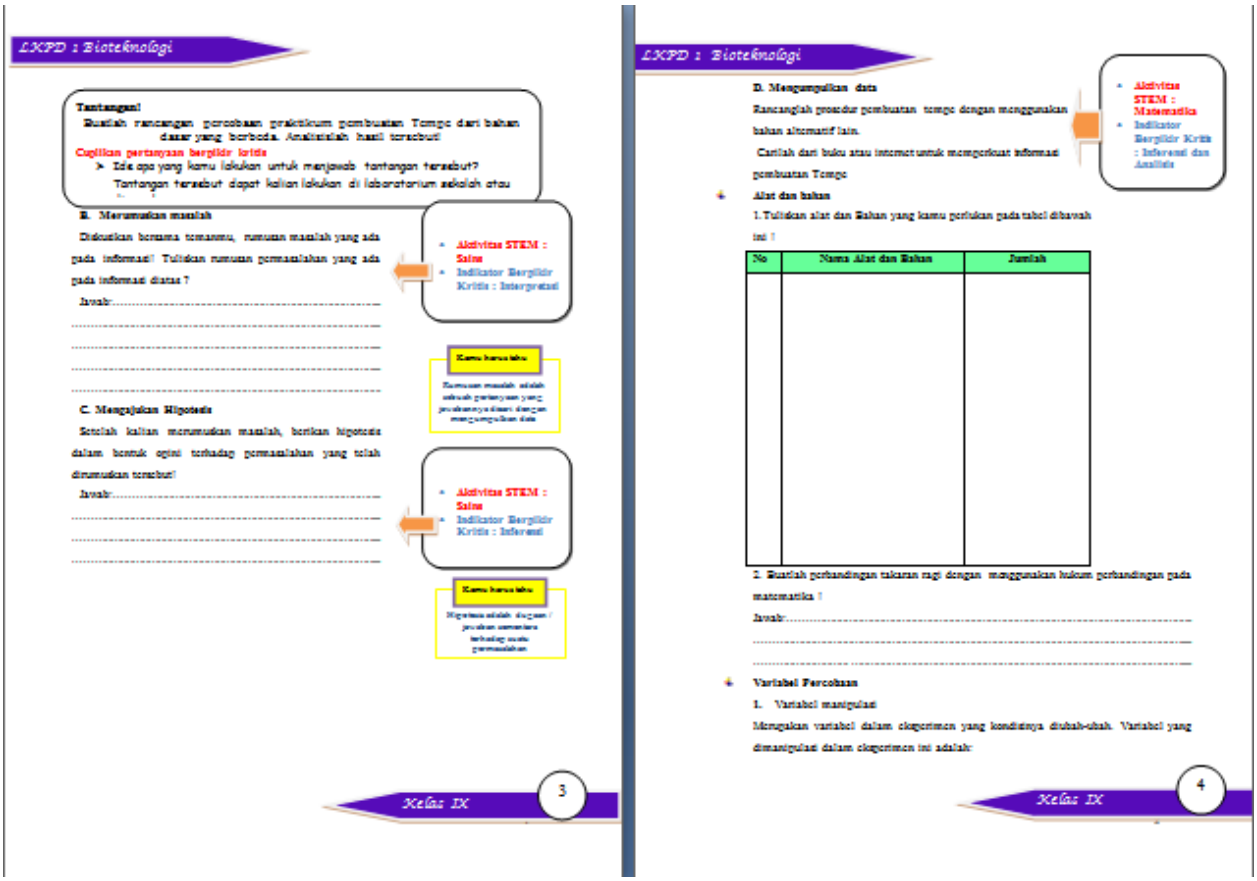

Figure 3. Steps to access critical thinking in STEM-based biotechnology student worksheet.

The results of the validation of the Worksheet tools developed are in accordance with the data in the Table 5.

Tabel 5. Validation student worksheet results.

No	Aspects	Rating Score			Average	Category
		Validator 1	Validator 2	Validator 3		
1	Content	4.00	4.00	4.00	4.00	Very Valid
2	Presentation	4.00	4.00	4.00	4.00	Very Valid
3	Language	3.00	3.00	3.00	3.00	Very Valid
Validation Average Score					**3.67**	**Very Valid**

Table 6. Colleration R counting devices student worksheet.

Category Aspects	R_{Count}	R_{Table} (5%)	Category
Content	0.97	0.97	Valid
Presentation	0.99	0.97	Valid
Language	0.99	0.97	Valid
Average	**0.98**	**0.97**	**Valid**

Table 7. Student worksheet reliability test results.

Cronbach's Alpha	N of Items
.864	15

The validation results listed in Table 5 show the average score of the validity results carried out by the three validators of 3.67. In addition, the analysis of the validity and reliability of the research instrument based on the validator's assessment was also analyzed using SPSS software. Based on the results of the analysis using the correlation coefficient (r), the average result of Rcount obtained a score of 0.98. Based on Table 5. it is known that the Cronbach's Alpha value in reliable statistics obtained a score of 0.864 or 86.4%. The validity of the Student Worksheet content, the presentation of the Student Worksheet, and the use of language in the Student Worksheet is said to be reliable if the Cronbach's Alpha value is > 0.6. In the calculation above, it is known that Cronbach's Alpha value is 0.864 > 0.6, so it is said to be reliable. In the results of the validation of the developed Student Worksheet, the results of the criteria are almost perfect in every aspect. Only in the assessment of language use still has a score that is less than the others. In this study, it can be concluded that the Student Worksheet developed has very valid and reliable criteria, so that the Student Worksheet is feasible to be used as a guide in learning activities. Similarly, the results of development research conducted by Syahbana (2012), Nur et al. (2014), and Hamidah et al. (2017) revealed that the validity of learning tools in measuring student abilities seen from content, presentation and language was included in the good category and could be used by doing a little revision.

Critical Thinking Ability Test Instrument

The development of critical thinking ability tests is based on the formulation of learning objectives that are associated with Blomm's level of thinking cognitive domain, namely the ability to restate concepts or principles that have been studied as intellectual abilities which include students' abilities to remember, remember (C1), understand (C2), apply (C3), analyze (C4), the concept of light (Mursalin et al., 2021). In addition, the making of this test instrument uses critical thinking aspects, which are developed to contain 4 critical thinking indicators which include aspects of interpreting, analyzing, evaluating and concluding (Rosnawati, 2015). The findings from the literature study reveal aspects and indicators of critical thinking. The learning outcomes test instrument developed consisted of pretest and posttest questions. Each test instrument consists of 6 essay questions which are arranged based on learning indicators on biotechnology materials that train students' critical thinking skills. This cognitive learning outcome test was reviewed by three validators. The results of the validation of the learning outcomes test instruments from the three validators are listed in Table 8.

Table 8. Validation results of critical thinking skills test.

No	Aspect	Rating Score			Average	Category
		Validator 1	Validator 2	Validator 3		
1	Content	3.00	3.00	3.00	3.00	Valid
2	Presentation	4.00	3.00	3.00	3.33	Very Valid
3	Language	4.00	3.00	4.00	3.67	Very Valid
Validation Average Score					**3.67**	**Very Valid**

Table 9. Correlation of critical thinking ability test variables.

Category Aspect	R_{Count}	R_{Table} (5%)	Category
Content	0.97	0.97	Valid
Presentation	0.97	0.97	Valid
Language	0.98	0.97	Valid
Average	**0.97**	**0.97**	**Valid**

Table 10. Results of critical thinking skills test reliability.

Cronbach's Alpha	N of Items
.793	15

The validation results listed in Table 8 shows the average score of the validity results carried out by the three validators of 3.67. In addition, the analysis of the validity and reliability of the research instrument based on the validator's assessment was also analyzed using SPSS software. Based on the results of the analysis using the correlation coefficient (r), the average result of Rcount obtained a score of 0.97. Based on Table 10, it is known that the Cronbach's Alpha value in reliable statistics obtained a score of 0.793 or 79.3%. The validity of the critical thinking ability test was developed based on the content of the questions, the presentation of the questions, and the use of language. The questions are said to be reliable if the Cronbach's Alpha value is > 0.6. In the calculation above, it is known that the Cronbach's Alpha value is 0.793 > 0.6, so it is said to be reliable. In the results of the validation of the cognitive test device that was developed, the criteria were almost perfect in every aspect, so it can be concluded that the critical thinking ability test developed has very valid and reliable criteria, so that the critical thinking ability test developed has valid and reliable criteria. This is in line with the research of Siregar (2020), Kurniawati (2020), and Putriadi et al., (2020). Learning outcomes tests are feasible to be used as evaluation materials. in learning activities in order to practice critical thinking skills. It should be noted that content validity is not a guarantee in identifying the measurement concept, but assessing content validity supports the construct validity of an instrument (Yaghmal, 2013).

Learning tools are tools to assist and facilitate learning activities to achieve the specified goals (Zancul, 2017). Learning tools are needed in managing learning in the form of lesson plans, student activity sheets, evaluation instruments or learning outcomes tests (critical thinking), and textbooks (Paintpasert & Jeerungsuwan, 2015). Good learning tools meet several criteria (1) Valid, namely the nature of being true according to evidence, logical thinking, or the power of law. (2) Practical, ie if the device can be used easily for teachers and students in accordance with the wishes of the device developer. (3) Effective, ie students give a good response (positive) to the learning program and learning takes place in accordance with what the developer wants and student learning outcomes (critical thinking) increase (Kuhlthau et al., 2017).

CONCLUSION

STEM-based biotechnology learning tools to train junior high school students' thinking skills that have been developed are suitable for use in school learning. The tools developed are lesson plans, student worksheets, and critical thinking questions which have presentation results of 97.4%, 86.4%, and 79.3% which are calculated using SPSS 23

software. Based on the experience of researchers while conducting research, this research was only carried out until the development stage. Therefore, it is necessary to do further research at the dissemination stage and it is necessary to develop integrated science learning tools on other subject matter.

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