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A Microbiology Module Development on Antagonism Between Fungi and Bacteria Based on Problem-Based Learning to Improve Student's Critical Thinking Skills

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ABSTRACT
The purpose of the research is to develop Microbiology Module on the topic "The Antagonism of *P. chrysogenum* against *Escherichia coli, Staphylococcus aureus*, and *Bacillus subtilis*" that have criteria valid, practice, and effective for improve the student's critical thinking skills. This research type is a quasi-experiment research using a non-randomized pretest-posttest control group design. The learning model uses the ADDIE approach which is implemented with the Problem Based Learning (PBL) model. Data collection uses response questionnaires, pretest and post-test, and validation sheets. The effectiveness of the Microbiology Module in improving students' critical thinking skills can be known through the pretest and post-test scores analyzed through the One Way Ancova test. The research and development result proved that the validation score gives by media and teaching materials experts was 99%, material experts were 98%, and Biology education practitioners were 100% from the student responses were 93%. The p-level results showed 0.00<0.05, so the modules were effective to use in the learning process. The research results proved that a significant difference between the experimental class learned using the Microbiology Module compared to the control class PowerPoint without the Microbiology Module. The modules is valid, practical, and effective to use in improve the student's critical thinking skills.

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1. INTRODUCTION

Critical Thinking Skills are the student's ability to evaluate or investigate and solve the daily life problems (Nuridayat et al., 2020). The efforts to improve critical thinking skills in learning require if mastery in daily life concepts based on each student's experience. Based on this description, critical thinking skills could be obtain by Biology practical learning process.

The learning of Microbiology courses must be in the form of student-centered, where students can discuss, present, and do practicum about the daily life for mastery in Microbiology concepts. The phenomenon that occurs in the environment around students is Antagonism Between Microbes, for example, between fungi and bacteria.

One of the interactions between microbes is antagonistic between fungi and bacteria. Some fungi can produce source compounds that can inhibit the bacteria growth. The compound is an antibiotic which can inhibit the pathogenic bacteria growth. The fungi can be use as a source for make nature friendly antibiotic. This reserach used *Penicillium chrysogenum* as an antibiotic-producing fungi such as penicillin, while *Escherichia coli, Staphylococcus aureus,* and *Bacillus subtilis* as pathogenic bacteria that cause infection diseases.

Based on results of needs analysis from Biology students who have attend the Microbiology course show a low critical thinking skills. Only 52.9% of students answered correctly to the question about the cause of bacterial growth inhibition due to antagonistic fungi activity. In addition, only 57.1% of students answered correctly to questions related about fungi species that can be used as a source of natural antibiotics. Low critical thinking skills can be caused by students difficulties in understanding the science concepts (Kusmianty et al., 2020).

The efforts to improve critical thinking skills in learning are carried out using the right learning models, learning strategies, and teaching materials. The preparation of these three factors must be adjusted to the conditions and students needs. Efficient and effective learning objectives require a teaching media to convey the informations from teachers to students through the right teaching materials (Puspitarini & Hanif, 2019; Sari & Setiawan, 2018).

There are several criteria in choosing teaching materials, the learning media must be related to the purpose of the learning process, the students condition, the efficiency to use the media, the process of delivering materials, and the availability of media to be used (Ramdhani & Muhammadiyah, 2015). The teaching materials used in this research are in the form of research-based modules that conducted by the researchers themselves in the laboratory.

Research-based teaching materials contain descriptions of basic materials, practical guidance, evaluations, and structured assignments that students have done to make the application, especially the concepts that student have learned (Fitriyah et al., 2015). This research-based teaching material is more interesting because it not only contains a description of the material but also presents facts from the research results conducted by the researchers and scientifically proven. Some of the teaching materials that can be used are textbooks, handouts, and modules. The results of the needs analysis show that the types of learning media that have been used in learning so far are 100% using practical manuals. Based on this, the use of modules in learning has yet to be implemented, so as many as 100% of students stated that it is necessary to create a research-based Microbiology Module to help improve students' critical thinking skills.

Modules are teaching materials that are arranged briefly and specifically based on material and learning evaluation. The modules are packaged systematically, interestingly, clearly, and equipped with pictures in the practical instructions, especially in the work steps, so the module is easy to learn independently anytime and anywhere according to the student's needs (Sirate & Risky, 2017). The research-based Microbiology module was developed using the PBL (Problem-Based Learning) learning model.

PBL is a learning model that provides a problem related to phenomena in daily life, so students are required to solve these problems in groups (Wulandari & Shofiyah, 2018). This PBL-based learning model can improve critical thinking skills. Therefore, the researcher chose the PBL model to enhance critical thinking skills. The research purpose is to prove the validity, practicality, and effectiveness of the Microbiology Module on "The Antagonism of *Penicillium chrysogenum* against *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus subtilis* Bacteria" to improve student's critical thinking skills.

2. RESEARCH METHOD

The type of research used in Research and Development (R&D) with the ADDIE development model. The ADDIE learning model consists of five stages: analysis, design, development, implementation, and evaluation (Branch, 2009). The stages of the ADDIE development model are presented in Figure 1.

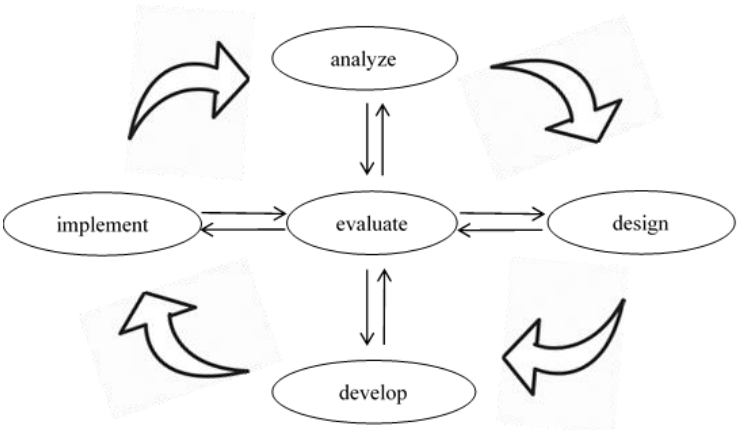

Figure 1. Stages of the ADDIE Model
Source: (Branch, 2009: 10)

The research population is S1 Biology Program 2022 FMIPA student from State University of Malang, who are taking the Microbiology course. The research sample consisted of 26 students from J class as an experimental class and 26 students from H class as a control class. The research design used non-randomize control group pretest-posttest design (Leedy & Omrod, 2015). The research implementation design with non-randomize control group pretest-posttest design is presented in Table 1.

Table 1. Non-Randomize Control Group Pretest-Posttest Research Design

Group	Pretest	Treatment	Posttest
Control	O1	X1	O3
Experiment	O2	X2	O4

Source : Leedy & Omrod (2015: 233)

The data in this research are quantitative data assessment scores from validators and respondents, as well as pretest and posttest results. Qualitative data are obtained from criticism and suggestions from validators and student respondents. Quantitative data analysis from the validator assessment uses the following formula.

$$V = \frac{Tse}{Tsh} \times 100$$

Source: (Akbar, 2013)

Information :
V : Validity percentage
TSE : Total score of completing validation questionnaire
TSH : Total maximum score for completing the validation questionnaire

The module validity criteria from validator assessment can be inferred by using the following criteria.

Table 2. Validity Criteria for Microbiology Module

No	Validation Criteria (%)	Validation Level
1	81,00% - 100%	Highly valid, or can be used without repair
2	61,00% - 80,00%	Quite valid or usable but needs minor improvements
3	41,00% - 60,00%	Less valid, or recommended not to be used because it needs major improvements
4	21,00% - 40,00%	Invalid, unusable
5	00,00% - 20,00%	Very invalid, unusable

Source: Modification from Akbar (2013: 41)

The data on student responses was analyzed using response percentage analysis. The calculation formula used is as follows.

$$\text{Response percentage} = \frac{Number\ of\ points\ that\ appear}{Number\ of\ ideal\ scores} \times 100$$

The data practicality from student's responses is determined with following criteria.

Table 3. Practicality Criteria of Microbiology Module

No	Percentage (%)	Validation Criteria
1	81,00% - 100%	Very practical or can be used without repair
2	61,00% - 80,00%	Quite practical and usable but needs minor improvements
3	41,00% - 60,00%	Less practical, or recommended not to be used because it needs major repairs
4	21,00% - 40,00%	Not practical, unusable
5	00,00% - 20,00%	Very impractical, unusable

Source: Modification from Akbar (2013: 41)

The effectiveness of the Microbiology Module is known based on the pretest and post-test scores. The prerequisite tests were a normality test using the Shapiro-Wilk One-Sample test and the homogeneity test using Leneve's Test of Equality from Error Variance. The influence and effectiveness of the Microb iology Module in the learning process are known based on the ANCOVA One Way Test result, so the module can be used to improve student's critical thinking skills. The Microbiology module is categorized as effective Module if the p -value < 0.05.

The implementation of the Microbiology Module for students who take the Microbiology course consists of two classes, namely the experimental class and the control class. The experimental class is taught using the Microbiology Module given before learning to learn. Control classes are taught without using modules but are explained using PowerPoint before practical learning. This module is integrated with the Problem-Based Learning (PBL) learning model. This learning can improve the student's critical thinking skills through PBL learning model.

3. RESULT AND DISCUSSION

The research and development result in this study are in the form of a Microbiology Module integrated with the Problem-Based Learning (PBL) learning model. The Microbiology module has module specifications in printed media based on the results of experimental research carried out by researchers in the laboratory. A description related to the content of the Microbiology Module is presented in Table 4.

Table 4. Systematics of the Microbiology Module "Antagonism Between Fungi and Bacteria"

No.	Module Contents	Module Aspects
1.	The Initial part	*Cover*
		Foreword
		List of contents
		List of Images
		List of Tables
2.	Introduction	SCPL, CPMK, sub CPMK, and Learning Objectives
		Module Usage Instructions
		Module Concept Map
3.	Contents Section: Learning Activity 1	**Learning Activity 1:** "Antagonism of the *Penicillium chrysogenum* Fungi against *Escherichia coli, Staphylococcus aureus,* and *Bacillus subtilis*" 1. Learning objectives 2. Description of material: a. Characteristics of the *Penicillium chrysogenum* Fungi b. Characteristics of *Escherichia coli, Staphylococcus aureus*, and *Bacillus subtilis* c. Some Examples of Antibiotic-Producing Fungi Species d. Antibiotics Mechanism in the Process of Inhibiting the Growth of Pathogenic Bacteria
4.	Contents Section: Learning Activity 2	**Learning Activity 2:** "Measurement Antagonism of *Penicillium chrysogenum* Fungi against *Escherichia coli, Staphylococcus aureus*, and *Bacillus subtilis*" 1. Learning objectives 2. Description of material: a. Test Method Antagonism of *the Penicillium chrysogenum* Fungi against *Escherichia coli, Staphylococcus aureus,* and *Bacillus subtilis* b. Testing Technique Antagonism of the *Penicillium chrysogenum* Fungi against *Escherichia coli, Staphylococcus aureus,* and *Bacillus subtilis* c. Antagonism Inhibition Zone of *Penicillium chrysogenum* Fungi against *Escherichia coli, Staphylococcus aureus,* and *Bacillus subtilis* Measurement Technique d. Antagonism of *Penicillium chrysogenum* Fungi against *Escherichia coli, Staphylococcus aureus,* and *Bacillus subtilis* Measurement Results
5.	Contents Section: Learning Activities 3	Student Activity Sheets
6.	Closing Section	Evaluation
		Glossary
		References
		Reseacher biography

The Microbiology Module contents are shown in Figure 2 and Figure 3. Figure 2 shows the cover page of the Microbiology Module "Antagonism Between Fungi and Bacteria," which contains 1) the Microbiology module title; 2) The microscopic images of antibiotic-producing fungi and bacteria that cause infections colonies; 3) the author and editor name; 4) the logo of the State University of Malang; 5) the identity of State University of Malang, faculty, study program, and year of publication. Figure 3 shows the table of contents of the Microbiology Module "Antagonism Between Fungi and Bacteria".

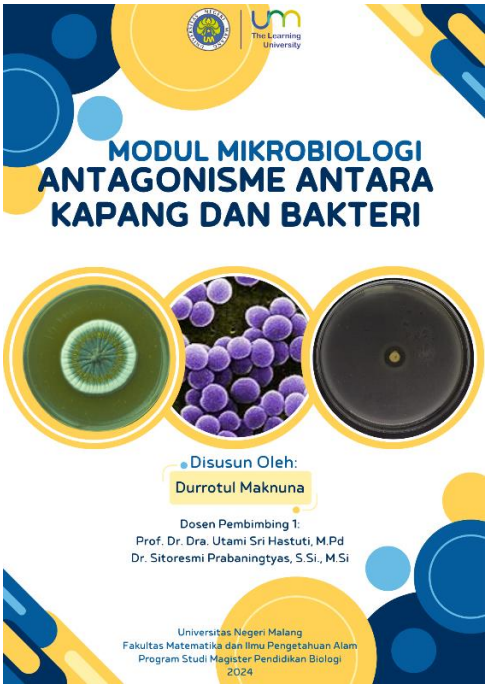

Figure 2. Cover of The Microbiology Module

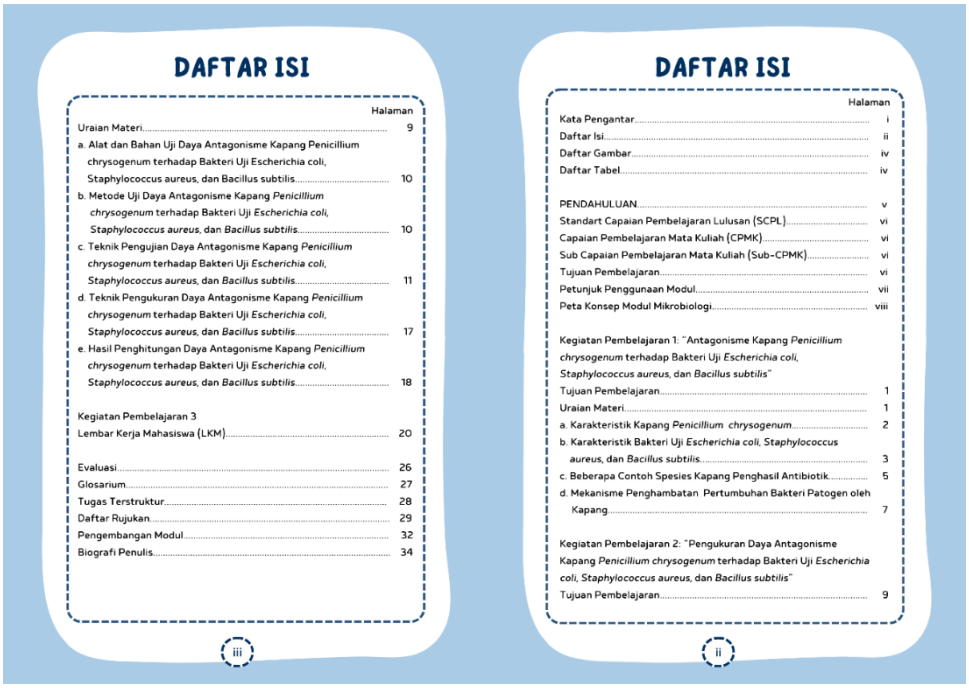

Figure 3. Table of Contents Microbiology Module

Furthermore, teaching material experts, material experts, and biology education practitioners conducted a feasibility test for the microbiology module. Feasibility tests are very important to ensure that the teaching materials used are suitable for the learning process (Widyaningsih, 2014). The quantitative data validated by the validators is shown in Table 5.

Table 5. Summary of Feasibility Test Results by Teaching Materials Experts, Material Experts, and Biology Education Practitioner Experts

No.	Validator	Percentage (%)	Criteria	Test Results
1	Teaching Materials Expert	99%	Very valid	Suitable for implementation
2	Material Expert	98%	Very valid	
3	Biology Education Practitioners Expert	100%	Very valid	

Table 5 shows validity results by teaching materials experts is very valid with a percentage of 99%. The validity test by a material expert is highly valid, with a percentage of 98%. The validity test by learning practitioners experts is very valid, with a percentage of 100%. Validity test to determine the feasibility level of the Microbiology Module that will be used in the learning process (Nesri et al., 2020).

The practicality test was carried out from the student response questionnaire. The practicality test results can be seen in Table 6. The practicality criteria was obtained by a percentage of 92,50% with very practical criteria.

Table 6. The Practicality Results of the Microbiology Module by Students

Respondents	Percentage (%)	Criteria	Test Results
Students of the Biology study program	92,50%	Very practical	Practical to use

Based on these results, the Microbiology Module is suitable for use in Microbiology learning. The effectiveness test was carried out through the pretest and post-test scores analysis to improve students' critical thinking skills can be seen in Table 7.

Table 7. Average and Difference Pretest-Post-test Score in Critical Thinking Skills Improvement in Each Class

No.	Class	Critical Thinking Skills			Result
		Pretest	*Posttest*	Difference	
1.	Experiment	31.53	60.76	29.23	Increase
2.	Control	30.76	42.69	11.92	Increase

Table 7 shows an increase in student learning outcomes, which is indicated by an increase in students' critical thinking learning outcomes of 17.31. Furthermore, the pretest and post-test values were analyzed using One-Way ANCOVA to determine the hypothesis test. The prerequisite test with the normality test using the Shapiro-Wilk test, and the homogeneity test using the Levene Error Equivalence Variance Test. The prerequisite test results can be seen in Table 8, and the hypothesis test results can be seen in Table 9.

Table 8. Prerequisite Test Results for Critical Thinking Skills

No.	Variabel	Test Type		N	p	alpha	Result
1.	Critical Thinking Skills	Normality	Pretest	52	0.054	0.05	Normal
		Normality	Posttest	52	0.058	0.05	Normal
		Homogenity	Posttest	52	0.974	0.05	Homogeneous

Based on Table 8, the p-value for the normality and homogeneity test results is >0.05. The data shows that it is normally distributed and homogeneous.

Table 9. Results of the One Way Ancova Critical Thinking Skills Test

Source	Type III Sum of Squares	df	MS	F	p
Corrected Model	5817,391[a]	2	2908,696	11,199	,000
Intercept	15347,261	1	15347,261	59,089	,000
X_KBK	1569,314	1	1569,314	6,042	,018
Kelas	4111,755	1	4111,755	15,831	,000
Error	12726,839	49	259,731		
Total	157700,000	52			
Corrected Total	18544,231	51			

Based on Table 9. The Microbiology Module influence test results proved that the p-level value of 0.00 < 0.05 meant that the use of the Microbiology Module was effective in on students' critical thinking skills improvement. Therefore, it was proved that the use of the Microbiology Module is able to critical thinking skills improvement for students.

4. CONCLUSION

Based on the results of the validity test of the problem-based learning-based microbiology module by media and teaching materials experts, material experts, and Biology education practitioners. The research and development result proved that the validation score gives by media and teaching materials experts was 99%, material experts were 98%, and Biology education practitioners were 100% from the student responses were 93%. The validation results show a very valid category and can be used in learning in Microbiology course. The results of the practicality test obtained an average score of 92,50% classified as a very practical category. Based on the results of the validity and practicality tests, it can be concluded that the module developed has a high level of validity and is easy to use in learning microbiology. The results of the feasibility test in the form of normality and homogeneity tests get significance > 0.05 and data is normally distributed and homogeneous. Furthermore, the results of the One Way Ancova test obtained p-value of 0.000 <0.05, which indicates that there is a significant difference in science process skills between students in the experimental class and the control class. Based on these results, it shows the influence of learning using modules on students' critical thinking skills.

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