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The Development of a Microbiology Digital Handout Based on an Experimental Research to Improve Critical Thinking Skills

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ABSTRACT

The present study aimed to produce a valid, practical, and effective microbiology digital handout teaching material based on the results of an experimental research to improve students' critical thinking skills. This research was carried out in two stages, i.e. laboratory experimental research and development research. The experimental research was carried out in the microbiology laboratory of the Faculty of Mathematics and Natural Sciences, State University of Malang, while the implementation of the teaching material was carried out in Agricultural Industry Technology Study Program of the Faculty of Agriculture, University of Tribhuwana Tunggadewi Malang. The development research adopted ADDIE learning model and employed 2 classes, i.e. control and experimental classes. Both classes used problem-based learning (PBL) model, and the digital handout was given to the experimental class only, not to the control. The results of this research indicate that there was a difference in improving critical thinking skills between the two classes. The skills were found higher in the experimental class than the control. The mean N-gain score of the control class was 59%, while the experimental class 85%. Based on the independent sample test, the sig. (2-tailed) value was 0.000 < 0.05, indicating that there was a difference between the experimental and the control classes. Therefore, the microbiology digital handout developed based on the results of an experimental research was found effective to improve students' critical thinking skills.

Keywords:
Critical thinking; Digital handout; Microbiology

Introduction

Education plays an important role in making a well-educated nation. However, the fact is, Indonesians still have relatively low-level of education. One of the reasons is students relatively have low level of critical thinking skills as proven by several research finding out that university students in Indonesia only get 13–16% critical thinking skills scores in average for each indicator (Anugraheni, 2019; Astuti, 2016; Kirana & Kusairi, 2019; Wiyoko, 2019). According to the 21st Century Partnership Learning Framework, critical thinking skill is a must-mastered competency for university students as this skill can guide them to have an expertise or skills in certain fields. In addition, critical thinking skill is also found to be able to train students to habituate themselves to think scientifically to solve problems in their daily lives (Caceres., Nussbaum., Ortiz. 2020). One of the problems encountered daily in East Kalimantan Province, Indonesia, is the damage to jack plants *(Mangifera caesia)* caused by pathogenic mold infections. In general, students are often aware of plant diseases caused by pathogenic mold infections. However, they do not really understand how to control the mold infecting the plants in an environmentally-friendly manner. As such, it is important to improve students' learning method on biology subject to train the them to be able to think critically. Students are usually only aware of one method to control such pathogenic mold, i.e. using synthetic fungicide as commonly practiced by the communities in general. As the residues are spread to the surrounding environments, this method has negative impacts on soil, microbes, and human health (Fournier *et al.,* 2020; Santísima-Trinidad, 2018; Tao., 2020). Based on this rationale, it is necessary to consider using environmentally-friendly biological fungicides. One of the alternatives to replace synthetic fungicides is using antagonistic molds to biologically control the pathogenic molds infecting plants. Antagonistic molds have the

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ability to inhibit the growth of pathogenic molds. Commonly used antagonistic molds are *Trichoderma* and *Aspergillus* (Tian *et al.,* 2020; Alfiky 2019; Zhi-xiang 2020; Adnan 2019; El-debaiky 2017). Antagonistic molds have different abilities in inhibiting the growth of pathogenic molds. To determine the level of inhibition, an in vitro test must be carried out in a laboratory. The results of the test later on can be presented in a practical and effective digital handout as a teaching material to improve students' critical thinking skills.

In general, teachers in Indonesia use printed handouts as teaching materials that are designed without complementary teaching videos (Erlinda & Lelfita 2020; Rozalia. *et al.,* 2018; Saputra, *et al.*, 2020; Sari & Putri, 2020). Such handouts are not effective and practical to improve university students' critical thinking skills. Handouts are written learning resources containing various important concepts about one of the sections of a learning material (Sanaky, 2011). The researchers intended to develop a practical and effective digital handout teaching material that can be used to improve students' critical thinking skills. According to Nerita (2017), learning using handouts can increase student's activities and learning achievements, particularly in biology subject. Handouts that are designed with eye-catching contents, colors, and images can motivate students to study (Shofwunnada *et al.,* 2018; Costa 2001). The digital handout specifically designed by the researchers contained one learning material equipped with basic theories, practicum instructions with photos of the practicum activities, videos of the steps to conduct the practicum activities, structured assignments, and evaluation. The materials presented in the handout were based on the results of an experiment directly conducted by the researchers. The implementation of the experiment-based digital handout development requires development models. For such handout development, the implementation can use problem-based learning (PBL) model. PBL is a learning model that begins with a problem as the first step to gather and integrate new knowledge. This model facilitates students to learn by solving the problems around them authentically and to integrate their interdisciplinary knowledge. Based on these rationales, this research aimed to produce a valid, practical, and effective microbiology digital handout based on the results of an experimental research. The validity of the handout corresponded with the overall content of the teaching material; the practicality with the feasibility during learning session; and effectivity with the ability to improve critical thinking skills.

Method

This research was carried out in two stages, i.e. laboratory experimental research and development research. The experimental research was carried out in the microbiology laboratory of the Faculty of Mathematics and Natural Sciences, State University of Malang. The results of the experiment were then presented as a teaching material in a digital handout form. The development research adopted ADDIE learning model by Robert Matie Branch (2009), i.e. 1) Analyze, 2) Design, 3) Develop, 4) Implement, and 5) Evaluate. The analysis step was conducted by disseminating questionnaires to students to acquire information important for students, particularly on basic theories and practicums. The design step was then arranged based on the results of the analysis step. During the development step, handout materials were prepared; the handout was subsequently validated by material expert validators and teaching material experts; and the readability of the digital handout product was tested on respondent students. The implementation step was carried out on the students from two classes, i.e. control and experimental classes for Bioindustry Technology subject in the Faculty of Agriculture, University of Tribhuwana Tunggadewi Malang. The evaluation step was carried out on each step. After the prerequisite normality and homogeneity tests were carried out, the obtained data were then analyzed using independent sample test. See Table 1 for the research implementation design.

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Group	Pre-test	Treatment	Post-test
Experiment	P1	X1	P2
Control	P3	X2	P4

Table 1. Research implementation design

Note:
X1 : Learning using PBL model without the developed digital handout
X2 : Learning using PBL model with the developed digital handout
P1, P3 : Pre-test prior to the treatment
P2, P4 : Post-test after the treatment

Results

The research produced a microbiology digital handout as a teaching material entitled "Test on the Antagonism Level between Antagonistic and Pathogenic Molds on Plant *Mangıfera caesia* Jack*"*. The handout was prepared and developed using software Microsoft Word 2016 and finalized using Flip PDF Builder. See Table 2 for the content of the digital handout developed in this research, the link https://online.flipbuilder.com/ggrc/xsgx/ for the display of the handout, or Figure 1 for the snippets.

Table 2. The content of the digital handout

Handout Content	Notes
Opening Section	Cover, Foreword, Table of Content, List of Figures
Main Section	CHAPTER I INTRODUCTION A. Learning Outcomes B. Learning Objectives C. Instruction CHAPTER II SUPPORTING THEORIES A. Jack Plant (*Mangifera caesia)* B. Pathogenic Molds on Jack Plant C. Antagonistic Mold *Trichoderma* sp. D. Antagonism Level between Antagonistic and Pathogenic Molds on Plant *Mangifera caesia* E. Antagonism Mechanism between Antagonistic and Pathogenic Molds on Plant *Mangifera caesia* CHAPTER III PRACTICUM ACTIVITIES 1st Practicum Activity 1st Practicum Activity Video 2nd Practicum Activity 2nd Practicum Activity Video CHAPTER IV STRUCTURED ASSIGNMENT EVALUATION

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Closing Section	Glossary, References, and Authors' Curriculum Vitae

Figure 1. The snippets of the digital handout. Note: (a) Cover, (b) Introduction Chapter, (c) Practicum Instruction Chapter

The prepared and developed digital handout teaching material was then tested for its effectivity in improving students' critical thinking skills. The test was carried out on 2 classes, i.e. control and experimental classes. Based on the Kolmogorov-Smirnov normality test, the significance was 0,637 > 0,05, while based on Levene's homogeneity test, the significance was 0,231 > 0,05, indicating that the data were found to meet normal and homogeneous prerequisites. See Table 3 and 4 for the effectivity tests of the digital handout in improving critical thinking skills.

Table 3. N-gain score test

	CLASS	N	Mean	Std. Deviation	Std. Error Mean
Critical thinking skills	Control	24	59.3276	11.5198	2.35148
	Experimental	24	84.9766	8.72158	1.78028

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Table 4. ***Independent Sample T-Test***

Variabel	Class	Rata Rata ± SD	Selisih Rata Rata	P value
Critical thinking skills	Control	59,33 ± 11,51	-25,65	0,000
	Experimental	84,98 ± 8,72		

Based on the tables above, the N-gain score for the control class was 59,33%, while the experimental class 84,98%. The value from the subsequent independent sample test was 0.00 < 0.05. These results indicate that there was a difference between the control class that used PBL model without the digital handout and the experimental class that used PBL model with the digital handout.

Discussion

The digital handout teaching material that was developed based on a laboratory experimental research was found to have a highly significant effect. As the experimental research was conducted directly by the researchers, it was factual and the researchers were able to explain to the students in a great detail during learning sessions. The significant effect was evidenced by the difference found between the control and the experimental classes. The mean N-gain score of the learning outcome of the control class was 59,33%, while the experimental class 84,98%. In addition, the result of the independent sample test showed that the sig. (2-tailed) was 0.000 < 0.05. These results indicate that there was a difference between the control and the experimental classes in improving critical thinking skills where the experimental class was found to have higher critical thinking skills than the control. Based on these results, the development of the microbiology digital handout based on an experimental research was found effective in improving students' critical thinking skills. This was due to the developed digital handout's positive aspects, among others (a) the theories presented in the handout were the results of the experimental research carried out in the laboratory, (b) the display was designed to be eye-catching with the complementary distinct images and videos of practicum activities, and (c) the materials were provided in a digital handout form, making it easier for the students to read and study anywhere. Textbook materials developed based on experimental research are more effective to be used in learning as they are more applicative and have a novelty, making it easier for students to understand concepts (Permin & Pernita 2012; Ulin *et al*., 2012). In addition, the results of this research were also in line with Nerita *et al.* (2017) who stated that learning using PBL model can improve students' critical thinking skills. Warnock & Mohammadi-Aragh (2016) also found out that applying PBL model into students' learning for one semester can improve their skills in solving problems and independent learning. Seyhan (2016) stated that the objectives of applying PBL model are to build broader and more flexible foundations of knowledge, to develop skills in solving problems, and to become an effective collaborator.

Conclusion

A microbiology digital handout based on an experimental research was successfully developed. Based on the results of this research, the handout was found to be able to improve students' critical thinking skills with the mean N-gain score 59,33% for the control class and 84,98% for the experimental class. Based on the result of the independent sample test, the sig. (2-tailed)

value was 0.000 < 0.05, indicating that there was a difference between the experimental and the control classes. Therefore, the microbiology digital handout based on the results of an experimental research was found effective to improve students' critical thinking skills.

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