Project-Based Learning in the Study of Eco-enzyme Microorganisms to Train Students' Critical Thinking in Waste Treatment Engineering Course

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Abstrac Critical thinking skills are abilities that must be possessed in life in the 21st century. Learning in higher education must be able to train students to be ready to live life in the future by having critical thinking skills. Based on several research results, one of the learning models that is able to train critical thinking skills is project-based learning. This study aims to improve students' critical thinking skills by using a project-based learning treatment. This research is a pre-experimental study with a one group pre-test post-test design, conducted on a sample of 36 students of Biology Education Study Program, Muhammadiyah University of Surabaya. To find out the increase in critical thinking skills after carrying out project-based learning, data analysis of pre-test and post-test results was used using normalized gain. The results of the study show that there is an increase in critical thinking skills after implementing project-based learning in the moderate category.

Keywords: project-based learning, critical thinking, Waste treatment technique

BACKGROUND

Critical thinking ability is one of the soft skills that must be possessed by students today (Robles, 2012)(Aliu & Aigbavboa, 2023)(Yeoh, 2019). This is in accordance with the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 49 of 2014 concerning National Higher Education Standards Article 6 which reads that graduates of the Undergraduate Program must have general skills, namely being able to apply logical, critical, systematic and innovative thinking in the context of the development or implementation of science and technology that pays attention to and applies the values of the humanities in accordance with their field of expertise..

Critical thinking ability is an intellectual capital that is very important for students (ŽivkoviĿ, 2016)(van Laar et al., 2017). Critical thinking skills can train individuals in choosing the right/best solution to the problems they face (Özsoy-Güneş et al., 2015)(Shaw et al., 2020)(Kong, 2014). In particular, in the era of globalization, it is very important for individuals to think critically in overcoming various complex problems (Carnevale & Smith, 2013)(Kay & Greenhill, 2011)(Sousa & Wilks, 2018)(Flores et al., 2012). Therefore, the ability to think critically is something that needs attention in order to produce individuals who can meet global demands.

One alternative learning model that is possible to improve critical thinking skills is project-based learning. Project-Based Learning is a learning model that uses projects or activities as media (Kokotsaki et al., 2016)(Kaldi et al., 2011). Menurut Kemdikbud (2013), students carry out exploration, assessment, interpretation, synthesis, and information to produce various forms of learning outcomes. Project-Based Learning is a learning method that uses problems as a first step in gathering and integrating new knowledge based on experience in real activities (Biasutti & EL-Deghaidy, 2015)(Loyens et al., 2023). This learning emphasizes students with project assignments (Pedaste et al., 2015). In project-based learning, students are required to work together in a group, share ideas and manage time so that assigned projects can be completed on time (Santos et al., 2023)(Tsybulsky & Muchnik-

Rozanov, 2021). This learning also provides opportunities for students to plan, implement, and evaluate the resulting products to be more realistic (Younis et al., 2021)(Goyal et al., 2022)(Guo et al., 2020).

The project-based learning model can be an effective approach in the study of microorganism eco-enzymes in waste treatment engineering courses. This approach enables students to be actively involved in real projects involving the study and application of microorganism eco-enzymes in a practical context. The following are some project-based learning that can be carried out in the study of eco-enzyme microorganisms in an effort to develop critical thinking for students.

1. Microorganism Selection, Students can carry out research projects to study and select the most suitable microorganisms for the production of eco-enzymes. They can study scientific literature, isolate microorganisms from the surrounding environment, or use existing ones to compare the activity of the enzymes produced.
2. Production Parameter Optimization, Students can carry out a project to optimize the parameters of eco-enzyme production. They can change the fermentation temperature, pH, substrate concentration, or fermentation time to find the most optimal conditions for the growth and production of the microorganisms' enzymes.
3. Product Characterization, Students can carry out projects for the characterization of eco-enzyme products produced by selected microorganisms. They can analyze the composition of the enzyme, the activity of the enzyme, the stability of the enzyme and other relevant factors to evaluate the quality and potential use of eco-enzymes.
4. Practical Application, Students can undertake projects to test the practical application of eco-enzymes in a real environment. For example, they can use eco-enzymes for the treatment of organic waste, fertilizing plants, or cleaning up contaminated environments. They can monitor the effectiveness and results of eco enzyme applications as well as report their findings.
5. Sustainability Analysis, Students can carry out projects to analyze aspects of the sustainability of the use of eco-enzymes. They can study the environmental and social impacts of using eco-enzymes, carry out a life cycle analysis, or calculate the potential economic benefits that can be obtained through using eco-enzymes.

In project-based learning, it is important to provide sufficient guidance and support to students. Lecturers can provide explanations of the necessary theories and methods, as well as provide direction in planning and implementing projects. This project may also involve collaboration between students, lecturers, and external partners such as research institutions or industries related to the use of eco-enzymes.

Through project-based learning, students can develop practical, analytical, and collaborative skills in studying eco-enzyme microorganisms. They can also gain a more in-depth understanding of the potential applications and ecological benefits of microorganisms in waste treatment and sustainable practices.

This study is part of a pre-experimental study to improve students' critical thinking skills. This study aims to determine the ability to think critically through project-based learning in the study of eco-enzyme microorganisms in the waste treatment engineering course for biology education students, even semester of the 2022/2023 academic year.

Project Based Learning

Project-based learning is generally considered as an alternative to traditional learning which is more centered on the teaching staff. (Chen & Yang, 2019) showed moderate and large positive effects on students' academic achievement compared to traditional learning. Students can solve and evaluate a problem (Tsybulsky & Muchnik-Rozanov, 2019), present the results to an audience enabling them to acquire the knowledge and skills required (Chen & Yang, 2019). It is characterized by independence, cooperation, communication, and reflection from students in real life practice (Kokotsaki et al., 2016). More specifically, it allows students to learn by finding solutions, asking questions, debating ideas, designing plans, and communicating with others (Choi et al., 2019). Project-based learning encourages collaboration between students, while lecturers only act as guides during the project (Greenier, 2020).

Project-based learning is an efficient learning method in the development of 21st century skills, because it supports critical thinking, problem solving, interpersonal communication, collaboration, and leadership (Chu et al., 2017), problem solving creatively, flexibility, and originality (Duchovičová et al., 2018). It also helps develop the abilities, skills, attitudes and values of students which enable them to understand global challenges that are always changing (Chu et al., 2017). Independent learning is part of project-based learning, which makes students more responsible for all aspects of their assignments (Robertson, 2011). So that it is possible to deepen and expand knowledge, integrate knowledge into a comprehensive knowledge system, to realize the meaning and purpose of

knowledge. Students will learn to work independently and creatively, plan and complete their work, take responsibility for their work and overcome obstacles, work with information, present their own work, express themselves correctly and debate, cooperate, communicate, tolerate, accept other opinions, evaluate their work and that of others (Hwang et al., 2017).

Project-based learning is considered as a very useful method for mobilizing learners, interpretation of interesting educational material, acquiring new knowledge, and also for developing the personal profile necessary for collaboration with others and solving problems (Larmer et al., 2015). This makes a strong link between students' engagement in their own projects and their learning outcomes (Pedersen & Hobye, 2020). Project-based learning is considered an effective learning method. The foundation of project-based learning is the true idea that students should not learn abstract definitions, but rather they should learn by completing complex projects (Yon et al., 2002).

METHOD

This research is a pre-experimental study using the One Group Pretest and Posttest design with the treatment given is project-based learning, namely the project to identify eco-enzyme microorganisms from fruit and vegetable waste. The population in this study were undergraduate students of the Biology study program at Muhammadiyah University of SurabayaThe research samples were taken using purposive sampling technique. The number of samples taken was 36 students in semester 6, academic year 2022/2023 who had not studied the waste treatment engineering course, taking into account the compatibility of the research time and the basic abilities of the sample.

The instruments used in this research are description questions to test critical thinking skills before and after learning is carried out, as well as observation sheets to determine the implementation of the project-based learning model. The procedures carried out in this study, during the preparatory stage, the researcher developed learning tools and research instruments. After expert judgment on the instrument, instrument trials were carried out on semester 7 students of the biology study program who had studied eco-enzyme microorganism material and after that instrument analysis was carried out.

Test the validity of each item is done by using product moment correlation, with the following equation (Puth et al., 2014).

$$r_{xy} = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{(N(\Sigma X^2) - \Sigma X^2) - (N(\Sigma Y^2) - \Sigma Y^2)}} \quad (1)$$

The reliability test using the Cronbach alpha equation is as follows (Taber, 2018).

$$r_{11} = \left(\frac{n}{n-1}\right)\left(1 - \frac{\Sigma \sigma_i^2}{\sigma_t^2}\right) \quad (2)$$

The results of the instrument test show sufficient or high validity, although there are low ones. These questions also have a moderate level of difficulty, so the researcher decided to continue using all of these questions in the study. Meanwhile, the data processing technique is done by first giving a score for each description question. The scoring of critical thinking is adjusted to the rubric that refers to the ACTA (Assessment of Critical Thinking Ability) criteria, giving a score of 1 indicates that the answer includes answers with critical abilities level 1, a score of 2 indicates an answer at a level of critical abilities level 2, a score of 3 for level 3 abilities, and a score of 4 for level 4 abilities (White et al., 2011).

TABLE 1 Different Levels of Each Critical Thinking Ability

Level	***Critical ability* 1**	***Critical ability* 2**	***Critical ability* 3**
Level 1: There is no association or involvement with the data at all	Doesn't mention data in arguments	Not specifically mentioning learning materials	Does not mention data from the results of the study
Level 2: Does not critically involve data	Mention the data, but take it at face value	Designing a special study to address an unclear cause or a study of an unclear cause	Mentions the data but does not see that there are other possible interpretations
Level 3:	Mention alternative explanations of the data or weaknesses in the	Describes certain studies that address specific causes	Use specific data in arguing because of the

Analyze the critical data, including at least one ambiguity	study in the context of building arguments for one of the causes		causes of differences from the one they choose
Level 4: Critically analyze all of the data	Discussing all three studies in the context of building a case for one of the causes	Describe experiments to overcome all the problems raised in ability	Use data from all three studies in arguing for the causes of the differences in the one they choose

Improvement of critical thinking skills is obtained by processing the average score of pretest and posttest using normalized gain. According to Hake, to calculate the normalized gain value, use the following equation (Colt et al., 2011).

$$< g >= \frac{<skor\ post\ test> - <skor\ pre\ test>}{skor\ maks - <skor\ pre\ test>} \quad (3)$$

RESULTS AND DISCUSSION

The result of calculating the normalized gain for students' critical thinking skills is 0.31, which has a moderate increase category.

TABLE 2 Critical Thinking Skills Improvement

Improvement Aspect	<*Pre-test*>	<*Post-test*>	Maximum Value	<g>	Category
Critical ability 1	1,00	1,96	4	0,32	Medium
Critical ability 2	0,62	1,96	4	0,40	Medium
Critical ability 3	0,58	1,31	4	0,21	Low

In the aspect of critical ability 1, namely integrating conflicting knowledge into integrated conclusions presented in Table 2, it has increased by 0.32, so it is in the medium category. Most of the students were able to answer correctly and mention data related to various types of unused fruit and vegetable waste as ecoenzyme ingredients, with the 4 data provided, and some were able to explain their contents.

In the aspect of critical ability 2, namely the ability to design experiments to resolve ambiguity in new knowledge, in Table 2 it is known that the increase in learning outcomes is in the medium category. Based on the posttest score which has an average of 1.96, it shows that most students in this case can explain by designing a case study to make sure their opinion is correct, and some are already able to use analogies in proving their arguments.

In the aspect of critical ability 3, namely the ability to estimate other interpretations of certain knowledge has increased 0.21 which is categorized as low after treatment. The post test results which have an average of 1.30 indicate that some students still have difficulty explaining enzyme activity and analyzing enzyme activity using several methods.

An interesting learning model can be carried out using the project based learning model, although this learning requires careful and specific design, it can help students to play an active role in solving problems, making decisions, researching, presenting and creating documents. Project-based learning is designed to be used on complex problems that are required by students when conducting investigations (Nation, 2008)(MacLeod & van der Veen, 2020).

The steps of the project-based learning model consist of; (1) determining essential questions, (2) designing project plans, (3) monitoring project implementation, (4) conducting assessments, and (5) evaluating can improve and develop critical thinking skills (Hwang et al., 2017). Of the five stages in project based learning, the following are stages that are able to improve students' thinking skills. The stage of determining essential questions allows students to develop their thinking skills about a topic in the concept of ecosystems. In this stage, the essential questions posed require in-depth investigation to find answers to the problem. This requires students to improve their critical thinking skills by conveying logical reasons to identify everything relevant to solving problems. The stages of designing project planning apart from developing collaboration skills between group members are also able to improve critical thinking skills because everyone in the group must convey their ideas and ideas in making a project to be carried out.

The stages of monitoring project implementation, carrying out assessments and evaluations do not directly affect students' critical thinking abilities because at these stages more are carried out by lecturers. The lecturer monitors student activities while working on the project. The stages of project assessment are carried out to see the achievement of project results, evaluate the progress of each student, and provide feedback regarding the level of understanding achieved. Meanwhile, the evaluation stage is carried out at the end of the learning process, to reflect and evaluate the results of the projects that have been carried out.

Project-based learning by identifying eco-enzyme microorganisms from fruit and vegetable waste is carried out with the following steps:

1. Understanding of Concepts, students will learn the concept of fruit and vegetable waste, and its potential use in the production of eco-enzymes. They will understand that this waste can become a source of nutrition for microorganisms that can produce useful enzymes.
2. Identification of Waste Samples, students will collect samples of fruit and vegetable waste from markets, supermarkets or food processing facilities. They will select different types of waste, such as skins, scraps, or unused parts of fruits and vegetables.
3. Isolation of Microorganisms, students will perform the process of isolating microorganisms from waste samples. This step involves taking the sample, processing the sample to obtain the microorganism isolate, and culturing the microorganism on a suitable growth medium.
4. Identification of Microorganisms, students will identify isolated microorganisms using microbiological methods, such as observing the morphology of microorganisms under a microscope, Gram stain tests, or using biochemical tests to identify the genus or species of microorganisms.
5. Enzyme Activity Test, students will test the enzyme activity of the microorganisms identified. They will culture microorganisms in media containing specific substrates for the enzymes they wish to analyze. Next, they will carry out an analysis of enzyme activity using colorimetric or spectrophotometric methods.
6. Characterization of Enzymes, students will conduct further characterization of the enzymes produced by the identified microorganisms. This includes determining the optimal temperature, optimal pH, enzyme stability, as well as the kinetic profile of the enzyme.
7. Evaluation of Potential Use, Students will evaluate the potential use of the enzymes produced by these microorganisms. They will consider the application of enzymes in waste treatment, fertilizing plants, or other industrial needs. This assessment may include a literature review, group discussions, and comparisons with available commercial enzymes.
8. Reporting and Presentation, students will compile a project report which includes the results of identification of microorganisms, enzyme activity, characterization, and evaluation of potential uses. Apart from that, they can also do project presentations to share their findings and discoveries with classmates and lecturers.

Through this project-based learning, students will be actively involved in the process of collecting samples, isolating microorganisms, identifying, and characterizing enzymes from fruit and vegetable waste. They will also develop a better understanding of the potential uses of waste in the production of eco-enzymes and contribute to sustainable waste treatment efforts.

CONCLUSION

Based on the analysis of research data, it can be concluded that in general project-based learning in the study of ecoenzyme microorganisms in the Waste Management Engineering course can improve critical thinking skills in the medium categor. The project-based learning is carried out by identifying eco-enzyme microorganisms from fruit and vegetable waste with the steps, 1) Concept Understanding, 2) Identification of Waste Samples, 3) Microorganism Isolation, 4) Microorganism Identification, 5) Enzyme Activity Test, 6) Enzyme Characterization, 7) Potential Use Evaluation, 8) Reporting and Presentation.

Recommendations for further research are to provide assignments or project-based learning support modules, because when using this project-based learning model students become focused on project implementation.

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