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Project-Based Learning on Biotechnology Materials to Enhance High School Students' Creativity and Problem-Solving Skills

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Abstract: This study aims to improve students' problem-solving abilities and creativity through project-based biotechnology learning. The research was conducted at a public high school in Gunung Putri, Bogor. This study involved students of class XI science which were divided into 2 groups, namely the experimental class and the control class. The research method used quasi-experimental with non-equivalent pretest-posttest control group design. The instruments used essays, questionnaires and observations. The results of this study are supported by the n-gain value of problem-solving ability and creative thinking in the experimental class 0.73 (high) and the control class 0.53 (medium). Learning activities are very active and dynamic, students must communicate, be creative, think critically and collaborate. Student response was very enthusiastic. The conclusion of the research can be seen that project-based learning can improve problem solving and creativity of high school students.

Keywords: Project-based learning, problem-solving, creativity.

INTRODUCTION

Biology is one of the learning that can develop 21^{st} century skills, namely developing student life skills. Biology is one of the sciences consisting of content or materials, methods, products, attitudes and technology. In the biology learning needs to facilitate learning activities carried out by teachers in accordance with 21st century learning. The majority of students are likely first introduced to scientific process abilities, such as creating hypotheses, analysing data, formulating arguments based on evidence, and using and assessing models of systems, in biology as an academic subject (Caballero & Knight, 2013). According to Suprijono (2013) states that learning can be defined as a process, way and action of study thing. Biology learning should be directed at creating an active atmosphere and student participation in solving problems around students. Considering inadequate teaching strategies are the primary culprits of students' lack of comprehension and subpar performance in biology and other science classes (Wekesa & Ongunya, 2016)

Biotechnology is one of the topics in biology subjects. Biotechnology learning is an interdisciplinary learning in science education. Themes in biotechnology are related to various problems that exist in society. Students can easily get sources of teaching materials. Biotechnology learning carried out with discovery learning. In discovery learning students seek knowledge actively. Students try to solve problems with creativity, then students can find biotechnology concepts independently. Thus, students feel a meaningful learning experience. In the current era of the 21st century, learning has an impact on creativity development, problem solving, concern for the environment and independence in life. There are many purposes for biotechnology, and it has social, moral, and economic inside the form of potential threats to human life and environmental advantages (Nurlaely *et al*., 2017).

21st century skills require students to have all four skills at once, including: high order thinking skill (HOTS), problem solving, communication, teamwork and creativity. Students to have success in competition in a global society, the student must have the ability to communicate, create, think critically and be able to work together with others. The skills of students in schools really need to be developed by teachers in order to build quality human resources who are ready to compete in a variety of fields of society, particularly in science and technology.

In fact, Teachers have not been able to explore the quality of student skills. The limited knowledge and experience of teachers is the main cause. Teachers must use a student-centered approach and a wide variety of constructivism learning models. Based on the results of the TTCT (Torrance Test of Creative Thinking) test, there was a decrease in creative thinking starting at the age of kindergarten to adulthood (Kim, 2011). The decline is due to the approach that is still used in the form of teacher-centered learning, so that students do not play an active role in learning and have an impact on the potential skills of students who are not trained by the teacher (Kim, 2011). Teachers therefore demand a teaching strategy that enhances students' creativity and problem-solving skills.

Project-based learning is one of the learning models that can improve students' cognitive abilities and attitudes. Learning approach is student-centered and provides a meaningful learning experience for students. PjBL (Project based Learning) is an instructive model that is based on the constructivist approach to learning, which involves the building of resources from various perspectives during a social action and enables self-awareness of learning and knowing while dependent on context (Tamim & Grant, 2013). Learning strategy is the development of specific factual issues to create a variety of possible alternative solutions. So that learning feels more real and has an impact on the student's environment.

Characteristics of project-based learning: (1) a perception of purpose and clarity of long-term and short-term objectives, (2) a psychologically safe project environment and a determination to telling the truth, (3) A harmonious coexistence of informal and formal structures; (4) Communities of practice that transcend project borders; (5) Leaders who set the tone for learning and serve as models for reflective behavior; and (6) Systematic and collective reflection (Halil, 2008). Project-based learning to strengthen the students' ability to collaborate in teams (Kapp, 2009)(Salam *et al.,* 2016). Learning activities starting with the emergence of the latest topics. The issue is a problem that the pupil can resolve through experimentation or observation (Kizkapan & Bektas, 2017). In project-based learning, problem solving is a crucial component that comes from a constructivist idea (Meyer & Wurdinger, 2016). In association with experiential learning, these models provide a range of educational options that include self-directed, constructivist, and real-world learning experiences (Brundiers *et al*., 2010).

The ability to solve problems is a search for a solution to an issue so as to achieve the purpose. A process of finding a solution to solve a problem is paramount (Chiang & Lee, 2016). The stages of solving problems according to Polya are 4 stages, namely understanding the problem, looking for possible problem solving solution, putting it into practice, and evaluating the outcomes (Wismath & Orr, 2015). Problem solving ability must be developed in biology class, and one of the biology learning that can develop problem-solving ability is biotechnology material. Teachers should bring up problems that occur in society in general, so the pupils were challenged and motivated to create an innovative and creative ideas. The stimulation and main focus for student activities and learning is an issue (Chin & Chia, 2004).

Creative ideas emerge from the process of understanding the problem so that creative thinking inspiration will be formed. Creative ideas which is a challenging behavior to study because it touches almost all psychological processes, from the most fundamental ones like perception to the most complex things like analogical thinking and problem solving, as well as processes ranging from cognitive to affective-motivational ones (Krumm *et al.*, 2016). Creativity as a way to solve a problem by using various alternative answers to the problem.

The important thing about creativity is a person's ability to adapt to changes and solve problems that arise, be flexible to situations and think of alternative problem-solving solutions (Krumm *et al*., 2016). This indicates that a creative person will be able to adapt in various situations and conditions that require him to always think about solving his problems. This creative ability must be developed by the teacher. Based on the description of this study, it aims to improve the 21st century skills of class XII high school students in biotechnology materials through a project-based learning model that can improve problem solving skills and build students' creativity. so that this research is important to do as one of the steps to find solutions to grow students' skills and creativity.

METHODS

Quasi-experiments were used in the research method, and the phase of the research Pretest-Posttest Control Group Design Non-Equivalence. The participants in this study were XII science students of Yapida Senior High School in Bogor. The samples collecting used purposive sampling techniques, which are sample determination techniques with certain considerations (Sugiyono, 2009). The number of experimental both groups and control groups each class were 40 students. The variable measured is the ability to solve problems with the instrument used is a test of the description of the ability to solve problems. Creativity skills variable consisted of 2 variables, namely the assessment of cognitive aspects of creativity and an assessment of psychomotor aspects.

The data obtained were quantitative data based on the calculation of n-gain scores and inferential statistics. Inferential statistics consists of a normality testing, a Levene test and a hypothesis test. Analyze the material obtained from pretest and posttest data of problem-solving ability and creative thinking skills to determine n-gain. In addition to the variable data above, questionnaire of student responses in the learning process. A normality test and homogeneity test were tasted by using the levene test (Test of Homogeneity of Variance). The hypothesis was tasted by using t-test (Independent sample test).

RESULT AND DISCUSSION

The outcomes of this research include the test of problem-solving skills, the outcome of creativity and the outcomes of the questionnaire of pupil’s responses.

Problem Solving Ability

The research data in the form of pretest and posttest values will be used to calculate the n-gain value of the ability to solve problems. The difference in problem-solving ability improvement was carried out by comparing the average n-gain value between experimental classes using project-based learning and control classes using problem-based learning. In Figure 1, data from the

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comparison of the percentage of pretest, posttest and n-gain scores are presented to students' problem-solving ability between the experimental class and the control class.

Normality Test

Normality test is to assess distribution of data or distribution of data n-gain scores ability to solve problems of the two classes. The results of the normality test can be seen in Table 1.

Table 1. Normality Test Results n-gain Score Problem Solving Ability experimental class and control class

Data	Sig.	Decision
Control	0.060	Normal
Experiments	0.200	Normal

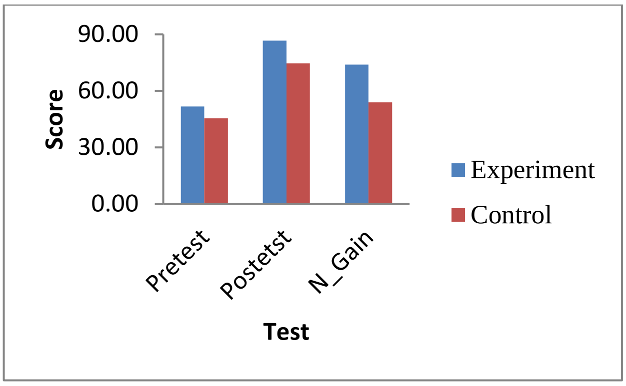

Figure 1. Graphic of the average score of N-Gain of Problem solving

Homogeneity Test

Test the homogeneity of data variance Problem Solving Ability of experimental and control class students using the Levene Test (Test of Homogeneity of Variance). Based on the results of the recapitulation of the n-gain data homogeneity test in the experimental and control classes with a significance value of > 0.05, so it can be concluded that the variance of the data is homogeneous. It can be seen in Table 2.

Table 2 Homogeneity Test Results n-gain Problem Solving ability in experiment and control classes

Data	Sig.	Decision
Control	0.19	Homogen
Experiment	0.87	Homogen

Hypothesis Test

The hypothesis using a parametric statistical test, namely the t-test with a significance value of < 0.05. The T test was conducted to see the difference in the n-gain scores of the two classes and the improvement of solving ability between the experiment and control classes.

The results of the hypothesis test of the ability to solve problems between the control class and the experiment are found in Table 3.

Table 3. Test Hypothesis n-gain Ability Problem Solving Ability of experiment and control classes

Data	**Asymp. Sig. (2-tailed)**	**Decision**
Control / **Experiment**	0.001	Significant

In the Table 3, it shows the results of the T test n_gain score in the control class and experiments with a Sig. 2-tailed asymp level of 0.001. The significance value is less than the research's critical limit value of 0.05, so the hypothesis decision is H_0 rejected, meaning that there is a significant difference in n-gain scores between the experiment and control groups.

Data Improvement on each indicator's problem-solving ability.

Hypothesis testing is also carried out at each stage of the ability to solve problems. There are 4 stages of problem-solving ability, namely understanding problems, presenting the possibilities of all problem-solving solutions, planning solutions, implementing solutions and evaluation (Wismath & Orr, 2015). To ascertain the improvement in problem-solving skills based on the evaluation results of each indicator in the control class and experiments shown in Figure 2 as an n-gain score.

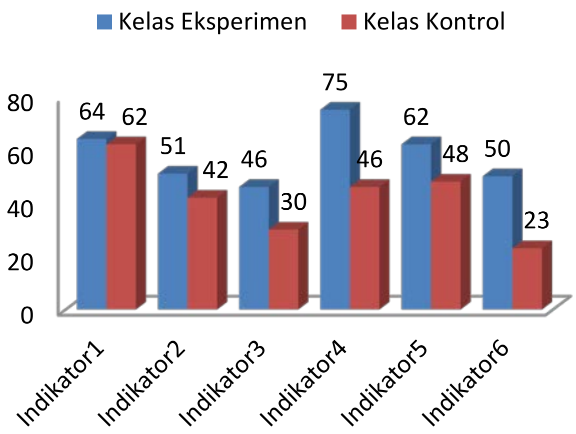

Figure 2. The result of the n-gain score of the ability to solve problems in each indicator

Creativity

Students' creativity is measured based on the cognitive dimension of creativity. Aspects that are sized in creativity, namely fluency, flexibility, originality and elaboration. From this aspect, there are 7 indicators that are presented in the instrument. The n-gain value in the experiment classroom and the instrument control classroom of creativity is found in Figure 3.

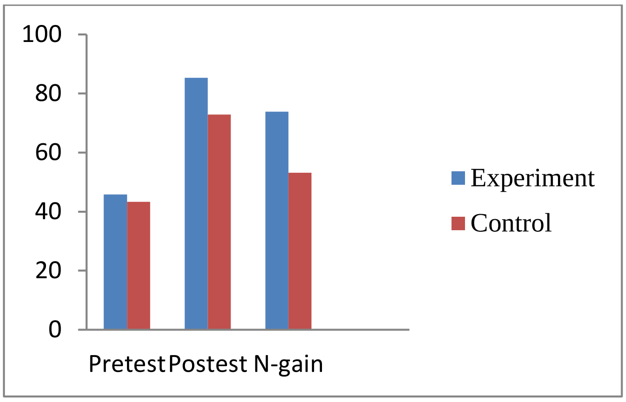

Figure 3. Diagram of pretest, posttest and n-gain scores on creative thinking skills instruments in experiment classes and control classes

Based on the graphic image above, it can be concluded that there is an effectiveness of learning in the experiment class to improve creative thinking skills compared to learning in the control class. The control class's n-gain score was 0.53 in the medium category compared to 0.73 in the high category for the experiment class.

Normality Test

Normality test used for analize the normality of the processed data. The data used comes from the n-gain score of the creativity instrument. The results of the recapitulation test of the normality of creative thinking skills are found in Table 4.

Table 4. Normality Test Results n-gain creative thinking skills scores in experiment classes and control classes

Data	Sig.	Decision
Experiment	0,200	Normal
Control	0,100	Normal

According to the normality test sources above, it shown by the n-gain score ujm; is normally distributed data. Sig value. the experiment class is 0.200, while the control class's sig. value is 0.100.

Homogeneity Test

Levene Test to determine the variance of the data on the students in the experimental and control classes' capacities for creativity (Test of Homogeneity of Variance).

Table 5. Homogeneity Test Results n-gain scores creative thinking skills in experiment and control classes

Data	Sig.	Decision
Control	0,159	Homogen
Experiment	0,446	Homogen

Based on the results of the recapitulation of the homogeneity test, the data scored n-gain in the experiment class (0.159) and the control class (0.446), with a significance value of >0.05, so it can be concluded that all data variances are homogen.

Hypothesis test

Hypothesis test is carried out after a prerequisite test is carried out on the data that has been obtained in the study. Based on the results of prerequisite tests carried out with normal distributed data and homogeneous data variance, the hypothesis test carried out using parametric tests is the T test with the help of

SPSS software version 25 for windows. The results of the T test in the experiment class and the control class are found in Table 6.

Table 6. Hypothesis Test Results *n-gain* creative thinking skills score in experiment classes and control classes

Data	Sig.	Decision
Experiment	0,00	Significant
Control		

Tabel 6 shows that the asymp Sig value. (2-tailed) in the N-gain data, it is 0.01, while the significance figure <0.05. Based on this it can be concluded that H_0 = rejected, so there is a significant difference in student's creative thinking skills between the experiment class and the control class.

Data on Each Aspect of Creativity Indicators

Aspects of creativity include fluency, flexibility, originality and elaboration. Of these 4 aspects, there are 7 indicators that are used as a reference to make instruments for creative thinking skills. The results of the analysis on each indicator are found in Figure 4. Each indicator of creativity test ability to have a wide variety of creative ideas and ideas, able to have many ways to solve problems and able to create original and innovative works.

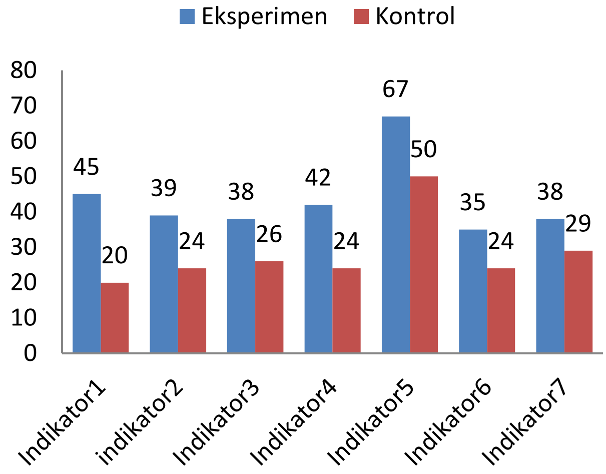

Figure 4. The result of *the n-gain* evaluation of creativity on each indicator

Student Response Questionnaire

Filling out the questionnaire is carried out after the project-based learning process to find out student responses to learning. The questionnaire consists of 4 indicators with 15 positive and negative statements. These indicators are attention, relevance, confidence and satisfaction with project-based learning. The following is a recapitulation of student response questionnaires to project-based learning in Table 7.

Table 7. Questionnaire Recapitulation of student responses to project-based learning

No	Indicators	Statement	Flat	Category
1.	Attention	1,2,5,13,15	95,8%	Good
2.	Relevance	3,4,6,9,12	83,8%	Good
3.	Confident	7,11	86,5%	Good
4.	Satisfaction	8,10,14	90%	Good

Problem Solving Ability

The experiment class (PjBL) is focused on being able to solve by making products that will be the solution to problems, so that it will make students have a more authentic learning The characteristic between project-based learning and problem-based learning is that it focuses on the issues surrounding the students and solves those problems. Problem solving skills is needed to improving food quality in biotechnology products that have good nutritional value quality for the human body. Project Based Learning structures around projects and places students in real-world settings where they can investigate and apply the material to challenging issues that are pertinent to the professional practice (Chiang & Lee, 2016).Competence in problem solving means having the capacity to think deeply, acquire, examine, and evaluate data in order to decide how to recommend a solution to problems or undesirable conditions (Phumeechanya & Wannapiroon, 2013).

In the experiment class, the teacher proposes a problem that will lead students to have the opportunity to apply skills, dig up information and create, than pupils can be problem solvers (Hanney & Savin-Baden, 2013). According to the posttest questions, both classes experienced an increase in scores on the indicators of determining the cause of the problem and making problem questions. For indicators to determine the causes of problems in the experimental class, 90% of students can provide the causes of problems and indicators for making problem questions in the experimental class, 60% of students make problem questions. As for the control class for indicators determining the cause of the problem, 50% of students gave the cause of the problem and indicators made questions, 40% of students made questions.

Based on the data above, improving the ability to understand this problem is also influenced by how students explore as much information as possible from the case studies provided by the teacher. Students in the experimental class who answered correctly at this stage was more than the control class. However, in the learning process the two classes began by understanding the problems that occurred around students and discussing in their respective groups and digging for more information outside of class hours. Students will find difficulties in solving problems, but in this process they will practice problem-solving skills (Chiang & Lee, 2016). Ozen states that understanding the problem correctly will help students in solving problems (Ozen, 2016). At the stage of understanding this problem is an important process that must be done by students in solving problem.

The subsequent level is when pupils can effectively propose a variety of answers, then students will be able to plan very appropriate solutions. In a project-based learning process, students not only understand the problem but also challenge students to plan feasible solution options (Brundiers *et al*., 2010). Based on student responses questionnaire that 90% of students can understand the concept of biotechnology after understanding the process of making biotechnology products. In the learning process students show activeness in digging up information about the problem. Students need to be able to work collaboratively with friends to complete projects in project-based learning.

Creativity skills

One of the main cognitive factors that must be taken into account when teaching science in the classroom is the ability to think creatively (Sari *et al.*, 2017). The ability to innovate, invent, apply new forms, generate a lot of creative ideas, or transform something that currently existing into something new are all aspects of creative thinking (Malang *et al*., 2017). Learning activities make students very enthusiastic in finding various kinds of creations in study groups. The products that students create widely, although there are some products that need to be evaluated. Thus, students are able to solve problems with creativity.

Biotechnology is an applied biological material, so project-based learning is very suitable for developing students' creativity. The observation results also show that student creativity is more developed when students plan product designs that are solution to problem solving. Creating biotechnology product ideas, students can hone their creative thinking abilities (Natadiwijaya, 2018). That scientific learning involves creativity abilities, particularly in biotechnology (Sari *et al.,* 2017). The lesson is related to the issue of food quality which is getting worse in Indonesia. The quality of nutrition in Indonesia is still in the category of worrying, especially the people's milk consumption is still low.

Another obstacle is the consumption of cow's milk is not liked by everyone. Based on these problems, students are expected to be able to solve problems by finding alternative food that can be consumed by the community. The design of a product really needs creativity to produce products that are original and liked by many people.

The study revealed that for each criterion of creative thinking abilities there was an increase in the posttest score compared to the pretest score. Each indicator of creativity showed 80% of students are capable of providing a variety of concepts, 96% of students can answer with many varied opinions, student are able to detail in great detail the design of the project or product to be implemented, 90% of students can generate their own ideas that bring up the novelty of a product. Project-based learning is able to learn without any restrictions, so that students are able to maximize their thinking power towards new things or new situations. Project-based learning has been shown in various studies to be an effective teaching technique for increasing student motivation for learning and encouraging participation in classroom activities (Chiang & Lee, 2016).

Students will be assisted in developing a more active and creative learning process through flexible learning settings, interaction, and responsive learning environment conditions. Constructivists contend that student participation and involvement in learning lead to the formation and construction of knowledge (Pursitasari & Permanasari, 2012). According to the survey of student opinions on project-based learning, 80% of participants believed that the model can help students enhance their creativity. 97% of students feel motivated in studying biotechnology with a framework of project-based learning. According to Badia, there was an increase in student creativity with the application of project-based learning (Badia, 2017). Revealed that the benefit most obtained was the development of students' creative thinking abilities, followed by knowledge and comprehension of the subject (Tamim & Grant, 2013).

CONCLUSION

The project-based learning offering students the chance to expand their knowledge, solving problems and design a new product. Project-based learning improves students' problem-solving and creativity greater than control group (PBL). The improvement of problem-solving and creativity occurs in each indicator of the problem-solving stage and the indicator of creativity skills. Students also responded positively to project-based learning. The implementation of biotechnology learning using project-based learning has been carried out as planned.

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