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# Improving problem-solving ability and collaboration skills of ecosystem material through STEM integrated project-based learning

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ABSTRACT

The learning process at Cipasung Islamic High School is still teacher-centered so the formation of 21st century skills in students is still neglected. The purpose of this study was to determine the effect of the STEM-integrated project-based learning model on the problem-solving ability and collaboration skills of students on ecosystem material. This research was conducted in May 2023. The research method used is an experimental method with a Quasi Experiment design and the matching-only posttest-only control group design form. The research population was the X MIPA class of Cipasung Islamic High School in the 2022/2023 school year. The sample was taken using a purposive sampling technique and obtained X MIPA 1 class as the control class and X MIPA 4 as the experimental class. The research instruments used in this study consisted of 3 validated instruments, namely the problem-solving ability test instrument, the CSAT (Collaboration Self-Assessment Tool) questionnaire, and the collaboration skills observation sheet. The data analysis technique used is One way ANOVA test. Based on the results of the analysis, it can be concluded that there is an effect of STEM integrated project-based learning model on problem-solving ability and collaboration skills of students on ecosystem material in Class X MIPA SMA Islam Cipasung.



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## INTRODUCTION

21st-century skills are important skills that must be mastered by every individual to face challenges in the 21st century. One of the 21st-century skills that are important for students to

have is problem-solving ability (Fitriana & Supahar, 2019) and collaboration skills (Alfaeni et al., 2022). Problem-solving ability is the basic process of identifying problems, considering options, and making informed choices (Supiandi & Julung, 2016). Collaboration skills are one of the skills that invite students to actively contribute in working together and interacting during learning so that learning will be easier to understand (Junita & Wardani, 2020).

Unfortunately, the results of the report from the Program for International Student Assessment (PISA) show that students' problem-solving skills in Indonesia are still relatively low when compared to other countries. (Ilmi, 2019). Based on various empirical findings in the research of Ayu et al. (2018) indicate low critical thinking and problem-solving skills, communication, and collaboration skills in school-age and working-age children. Ofstedal & Dahlberg (2009) also stated that the education field was very slow in realizing the need to teach collaboration skills to students. Collaboration skills are needed by students because these skills are more than just working together, including active listening skills, responding with respect, expressing ideas clearly through various ways of communicating, and using these skills to reach consensus and compromise (Sahrir, 2019).

Based on the results of interviews with Biology Teacher class X, the teacher has never measured and taught the problem-solving ability and collaboration skills of students. During the learning process, the teacher only explains the material and students listen to the explanation from the teacher so that from the learning process there is no process of forming students' basic skills, especially problem-solving ability and collaboration skills. Therefore, problem-solving skills are very important for students to have (Fitriana & Supahar, 2019). This is indicated by the development of learning models that demand the improvement of problem-solving skills (Fitriana & Supahar, 2019). Likewise, collaboration skills are one of the important aspects of lifelong learning (Sari et al., 2021).

Science learning including Biology in the 2013 curriculum has provided a reference in the selection of learning models that are by the scientific approach. These learning models include project-based learning (PjBL), problem-based learning (PBL), and discovery learning(Afriana et al., 2016). Project Based Learning (PjBL) is one of the learning models suggested in the implementation of the 2013 curriculum to be applied in learning (Budiharti et al., 2016). Project-based learning is a learning model that is relevant to the demands of the 21st century (Parno et al., 2020). PjBL is a student-centered learning model and provides meaningful learning experiences for students. Students' learning experience or concept acquisition is built based on the final product produced in learning. The characteristics of the project-based learning model according to Kemendikbud (2014) include the existence of problems posed to students and students being collaboratively responsible for solving problems. Based on these characteristics, there is a connection between project-based learning problem-solving ability, and collaboration skills.

In addition to project-based learning, learning today needs to follow the trends of the globalization era, one of which is by integrating science, technology, engineering, and mathematics known as STEM. Projects in PjBL are related to the fields of Science, Technology, Engineering, and Mathematics (Parno et al., 2020). STEM is a learning approach that connects four fields, namely science, technology, engineering, and mathematics into a holistic unit (Jauhariyyah et al., 2017). The STEM approach to learning is expected to provide meaningful learning for students through the systematic integration of knowledge, concepts, and skills. The project approach in STEM is based on constructivist theory which is proven to improve student achievement in higher-order cognitive tasks, such as scientific processes and problem-solving (Laboy-Rush, n.d.). The STEM approach aims for learners to have the skills to identify problems (Permanasari dalam Utomo et al., 2020) and develop collaboration skills ( Winarni et.al. dalam Utomo et al., 2020). This shows that STEM is related to problem-solving and collaboration skills.

Research on project-based learning (PjBL) integrated with STEM has been carried out but is still rare in Biology learning. This study integrates STEM with a project-based learning model to be applied to one of the Biology materials, namely ecosystems. The results of research by Parno et al. (2020) revealed that the use of a project-based learning model integrated with STEM can improve problem-solving skills and get a positive response from students to the implementation of the model. In addition, STEM in PjBL also provides challenges and motivation for students because it trains students to think critically, and analytically, and improve higher-order thinking skills (Capraro et al., 2013).

Ecosystem material is one of the materials taught in class X SMA where it discusses biotic and abiotic components and interactions between their components. This material is very supportive in the application of the STEM-integrated project-based learning model where students are required to make a project that is integrated with science, technology, engineering, and mathematics to train students' problem-solving skills and collaboration skills.

Based on the background description above, the author aims to research the effect of STEM-integrated project-based learning model on problem-solving ability and collaboration skills of learners on ecosystem material (experimental study in class X SMA Islam Cipasung academic year 2022/2023)". This research is expected to be useful for improving the quality of education in Indonesia, especially in improving students' problem-solving abilities and collaboration skills.

## RESEARCH METHODS

### Research Design

The research method used is a quasi-experimental design with the form of a matching-only posttest-only control group design. The matching-only posttest-only control group design can be seen in Table 1.

**Table 1.** The Matching-Only Posttest-Only Control Group Design

| | | | |
|---|---|---|---|
| Treatment group | M | X | O |
| Control Group | M | C | O |

Description:

M : Classes that have been determined as control/experiment classes
X : Experimental class with STEM-integrated project-based learning model treatment
C : Control class with discovery learning model treatment
O : Post-test

### Population and Samples

The population in this study were all X MIPA classes of Cipasung Islamic High School in the 2022/2023 school year consisting of six classes. The sample of this study used 2 classes. The sampling technique used in this study was purposive sampling. The samples in this study were X MIPA 1 class totaling 34 people and X MIPA 4 class totaling 34 people. The reason for selecting these samples is because class X MIPA 1 and class X MIPA 4 have an average score that is not much different and also based on consideration with the Xth grade Biology teacher. Class X MIPA 1 was the control class using the discovery learning model and class X MIPA 4 was the experimental class using the STEM-integrated project-based learning model.

### Instruments

The research instruments used in this study were a problem-solving ability test, CSAT(collaboration self-assessment tool), and collaboration skills observation sheet. The test instrument was used to measure students' problem-solving ability. The test form is an essay question that contains 5 indicators of problem-solving ability. The CSAT questionnaire is given to

measure students' collaboration skills which consists of 11 indicators. Then the collaboration skills observation sheet contains 4 indicators. The test instruments used have previously passed the validity test and reliability test. The questionnaire instrument is the result of the adoption of Ofstedal & Dahlberg (2009) ) research which was then translated into Indonesian. The results of construct validity conducted by expert validity show that the instrument is suitable for use. After construct validity, content validity was carried out on the test instrument using SPSS 26 software. Based on the results of the validity test on 20 questions, 9 questions were declared invalid and 11 questions were considered invalid. However, there was 1 question that was modified by changing the sentence structure of the question. The purpose of this modification is to complete the use of the instrument because this instrument is in the form of a question package that must contain 5 indicators. So, the number of questions used as a test instrument is 10. The result of the reliability test on 10 questions is 0.90. These results indicate that the instrument has a very high level of reliability. The grid of the problem-solving ability test instrument can be seen in Table 2.

**Table 2.** Grids of Problem-Solving Ability Instruments

| No. | Indicator | Question number | Number of question |
|---|---|---|---|
| 1 | Defining the problem | 1 and 6 | 2 |
| 2 | Diagnosing the problem | 2 and 7 | 2 |
| 3 | Formulate alternative strategies | 3 and 8 | 2 |
| 4 | Determine and implement preferred strategies | 4 and 9 | 2 |
| 5 | Evaluate the success of the strategy | 5 and 10 | 2 |
| | **Total** | | **10** |

The grid of the collaboration skills questionnaire instrument(Collaboration Self-Assessment Tool) can be seen in Table 3.

**Table 3.** Collaboration Skills Questionnaire Instrument Grid

| No. | Indicator | Item Number |
|---|---|---|
| 1 | Contribution | 1 |
| 2 | Motivation/participation | 2 |
| 3 | Quality of work | 3 |
| 4 | Time management | 4 |
| 5 | Team support | 5 |
| 6 | Preparedness | 6 |
| 7 | Problem solving | 7 |
| 8 | Team dynamics | 8 |
| 9 | Interaction with others | 9 |
| 10 | Role flexibility | 10 |
| 11 | Reflection | 11 |

The grid instrument of the collaboration skills observation sheet (Collaboration Self-Assessment Tool) can be seen in Table 4.

**Table 4.** Collaboration Skills Observation Sheet Instrument Grid

| No | Collaboration Skills Indicator | Observation Item |
|---|---|---|
| 1 | Productive work | 1,2,3 |
| 2 | Showing respect | 4,5,6 |
| 3 | Compromise | 7,8,9 |
| 4 | Sharing responsibility | 10,11,12 |

## Procedures

The research procedure consists of three stages, namely preparation, implementation and data processing. In the preparation or pre-research stage, researchers made observations to the school that would be used for research, made instruments, and tested research instruments. At the implementation stage, researchers collected data obtained from the posttest. Learning activities used the discovery learning model for the control class and the STEM-integrated project-based learning model for the experimental class. learning was carried out for 3 meetings on ecosystem material. The last stage is data processing, researchers process data obtained from the field and analyze all research results.

## Data Analysis

The data analysis technique uses descriptive statistical analysis to find the average of each class. Then the prerequisite analysis test was carried out, namely, the normality test using the Kolmogorov-Smirnov test and the variance homogeneity test using the Levene test. Hypothesis testing was carried out using the one-way ANOVA test. All data were analyzed using IBM SPSS software version 26.

## RESULTS

The post-test was given to students after being given treatment in each class using validated instruments. The research data first went through the prerequisite test stage of analysis, namely normality and homogeneity. The normality test results have a significance value of 0.05, meaning that all data comes from a normally distributed population. Furthermore, the homogeneity test shows that all data have homogeneous variances, so the hypothesis test used in this study is a parametric statistical test using the One-Way ANOVA test. The results of the One-Way ANOVA test analysis can be seen in Table 5.

**Table 5.** One-Way ANOVA Hypothesis Test Results

ANOVA

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Problem-Solving Ability | Between Groups | 612.000 | 1 | 612.000 | 60.659 | .000 |
| | Within Groups | 665.882 | 66 | 10.089 | | |
| | Total | 1277.882 | 67 | | | |
| Collaboration skills | Between Groups | 124.471 | 1 | 124.471 | 4.449 | .039 |
| | Within Groups | 1846.471 | 66 | 27.977 | | |
| | Total | 1970.941 | 67 | | | |

Then to see the effect simultaneously (together), a simultaneous test was conducted with the following results.

**Table 6.** Simultaneous Hypothesis Testing Results

ANOVA

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 612,295 | 2 | 306,148 | 29,898 | 0,000[b] |
| | Residual | 665,587 | 65 | 10,240 | | |
| | Total | 1277,882 | 67 | | | |

a. Dependent Variable : KPM
b. Predictors : (Constant), Class , Collaboration

The average score of each indicator of problem solving ability in the control and experimental classes can be seen in Figure 1.

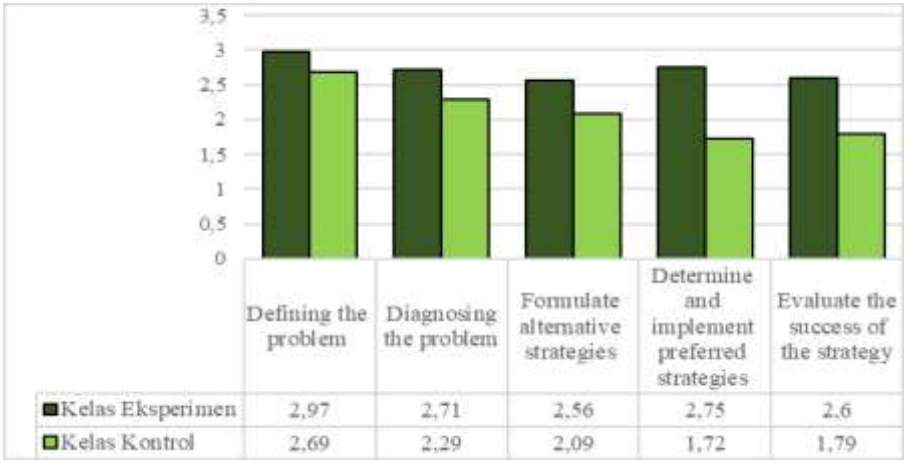


**Figure 1.** Comparison Diagram of Posttest Average Score of each Indicator of Problem-Solving Ability in Experimental and Control Classes

The acquisition of collaboration skills scores for each indicator in the control and experimental classes can be seen in Figure 2.

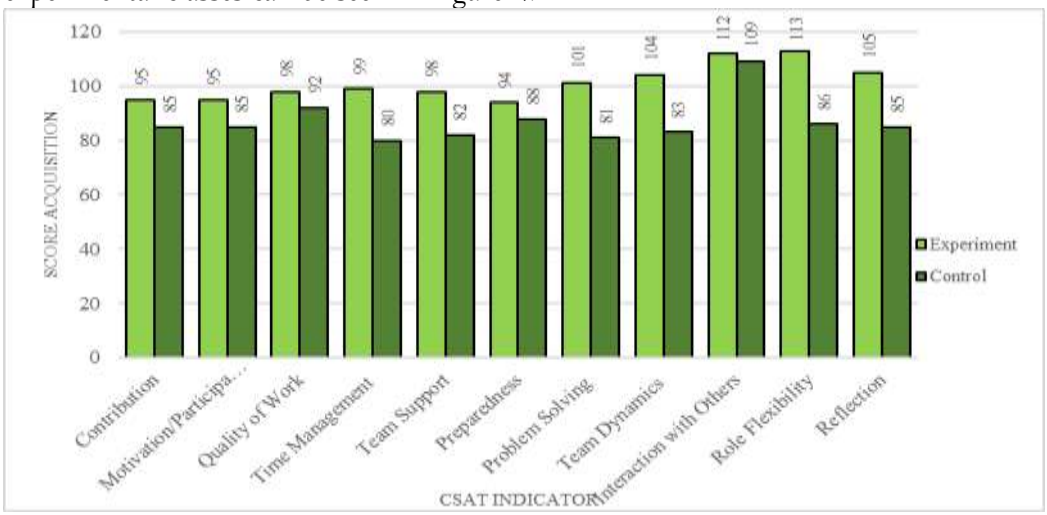


**Figure 2.** Comparison Diagram of CSAT Score Acquisition for Each Indicator of Collaboration Skills in Experimental and Control Classes

The measurement of collaboration skills is supported by observations that have been made by observers and the results obtained as in Table 7.

**Table 7.** Observation Results of Collaboration Skills

| Class | Indicator | Score | Criteria |
|---|---|---|---|
| Control | Productive work | 78,42 | Exemplary |
| | Showing respect | 89,21 | Exemplary |
| | Compromise | 58,27 | Proficient |
| | Sharing responsibility | 46,08 | Basic |
| Experiment | Productive work | 88,89 | Exemplary |
| | Showing respect | 91,83 | Exemplary |
| | Compromise | 65,69 | Proficient |
| | Sharing responsibility | 58,82 | Proficient |

## DISCUSSION

STEM-integrated project-based learning or STEM-PJBL is an approach that directs students to explore ill-defined problems that integrate STEM in a limited environment (Samsudin et al., 2020). The results prove that STEM-integrated project-based learning affects problem-solving ability and collaboration skills. Based on the results of hypothesis testing using the one-way ANOVA test in Table 5, where partially the STEM-integrated project-based learning model affects problem-solving ability with a significance value of 0.000 and affects collaboration skills with a significance value of 0.039. Then simultaneously obtained a significance value of 0.000 while the value of $\alpha = 0.05$ (0.000 0.05) which means H0 is rejected and Hq is accepted (table 6). This means that simultaneously there is an effect of using project-based learning integrated with STEM on the problem-solving ability and collaboration skills of students on ecosystem material in class X MIPA SMA Islam Cipasung in the 2022/2023 school year. This shows that the use of STEM-integrated project-based learning models has a positive influence on improving problem-solving ability and collaboration skills. In line with the research of Megawati et al. (2023) which shows that PjBL-STEM-based learning is effective for improving 21st-century skills including developing students' collaboration skills by providing opportunities for students to work together in teams through problem-solving in the given project.

Improving students' problem-solving ability and collaboration skills can occur due to several factors, one of which is the use of the STEM-integrated PjBL model. Learning with STEM-integrated PjBL invites students to do meaningful learning in understanding a concept and exploring through a project activity (Jauhariyyah et al., 2017). STEM-PjBL gives students experience in solving real problems with practicum activities so that it can increase effectiveness, and meaningful learning, and support future careers (Tseng et al., 2013).

The problem-solving ability of students is measured using a test instrument in the form of a description of 10 questions consisting of 5 indicators. The average score of each indicator of the problem-solving ability of the control and experimental classes contained in Figure 1 shows that the average of each indicator in the experimental class tends to have a higher value than the control class. This high score is because the learning stages in the STEM-integrated project-based learning model are in line with the problem-solving ability indicators where students are presented with a problem that they need to study (reflection stage in the STEM approach) first to understand the context of the problem and then formulate a solution in the form of a product that they will make. In addition, in PjBL learning integrated with STEM, there is also a research and discovery approach where students will research the problems presented so that students can identify problems including their causes. This is in line with the opinion of Supiandi & Julung (2016) where project-based learning has learning characteristics in the form of proposing problems that can train students in problem-solving habits that will affect students' higher-order abilities, for example getting students used to thinking creatively by exploring and expressing ideas, as well as identifying problem-solving that can be applied to solve given problems. Anugrah et al. (2020) added that learning is done by giving problems that are relevant to students' lives where students are asked to actively think so that they can solve the problems given.

Collaboration skills are the ability to participate in any activity to foster relationships with others, respect relationships and teamwork to achieve the same goal (Rahmawati et al., 2019). Collaboration skills in this study use the CSAT(Collaboration Self-Assessment Tool) questionnaire which consists of 11 indicators. Each indicator consists of 4 statements, so this questionnaire totals 44 statements. The score is then categorized into 3 criteria, namely emerging, developing, and established (Ofstedal & Dahlberg, 2009). Based on the research results, the "emerging" criteria consisted of 6 respondents from the experimental class and 8 people from the control class. The criteria for "developing" in the experimental class were 19 people, while the

control class was 24 people. Then for the "built" criteria, there were 9 people from the experimental class and 2 people from the control class.

The acquisition of experimental and control class CSAT scores for each indicator contained in Figure 2 shows that the scores of all experimental class indicators are higher than the acquisition of control class scores where it can be seen that the highest score for the experimental class is in the flexibility indicator, while the lowest score is in the preparation indicator. The flexibility indicator score is 113 which is the highest score. This high score is because the experimental class learning using the STEM-integrated project-based learning model emphasizes the collaboration process in making projects to stimulate students to adapt flexibly to lead their groups and as members (Ofstedal & Dahlberg, 2009). Meanwhile, the preparation indicator score was 94. The low preparation score can be caused by learners not being accustomed to doing assignments that are project making so learners are not used to preparing the things needed in making projects. Ofstedal & Dahlberg (2009) suggest that the preparation referred to here is the readiness of students to work when they come to class. In this case, students in the experimental class are not accustomed to preparing in advance for the needs of working in groups.

In addition to the CSAT questionnaire, the assessment of collaboration skills is also measured by the collaboration skills observation sheet. Referring to the results of the observation of students' collaboration skills in the control class contained in Table 7, the highest score is on the indicator "showing respect" with a score of 89.21 which is included in the exemplary criteria. The lowest score is on the "sharing responsibility" indicator with a score of 46.08 which is included in the basic criteria. Similar to the experimental class, the highest score for the experimental class on the indicator "showing respect" with a score of 91.83 including exemplary criteria, and for the lowest score there is also an indicator "sharing responsibility" with a score of 58.82 which includes proficient criteria. The indicator of showing respect can be seen in group members who are openly willing to listen to and respect the opinions of their fellow members during discussions. As for the indicator of sharing responsibility, some group members have not completed the tasks that are their part. The attitude of collaboration is very important to be familiarized to students so that students have good academic performance to solve problems in project work (Hidayanti et al., 2020).

## CONCLUSION

Based on the results of research, data processing, and hypothesis testing, it is proven that there is an effect of the STEM-integrated project-based learning model on the problem-solving ability and collaboration skills of students on ecosystem material in class X MIPA SMA Islam Cipasung in the 2022/2023 school year. The conclusion of this study states that the STEM-integrated project-based learning model is effectively used in learning biology, especially on ecosystem material to improve students' problem-solving ability and collaboration skills.

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