The impact of implementation of STEM integrating project-based learning on students’ problem-solving abilities

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Abstract. Problem solving is one of the higher thinking skills required and must be built by students. This study aims to examine the ability of students to solve problems through the implementation of the STEM approach integrating PjBL model on the Immune system. This study was carried out at senior high school in Banda Aceh and Aceh Besar district. This study was an experimental pretest design with a non-randomized control group. The population was all 11th-grade students from both schools. Thus, the Science Class 1 and 3 (of SMAN 5 Banda Aceh) and the science class 1 and 4 (of SMAN 1 Darul Imarah) were selected as the sample. The test attached in the student working sheets, which was constructed using an Engineering Design loop, is the instrument used to assess the problem-solving capacity. The data from the study have been processed and descriptively analyzed. The results showed that the STEM approach integrating PjBL model could improve the abilities of students to solve problems. Therefore, the implementation of STEM approach combined with PjBL can be used as a strategy for teachers to carry out learning activities to enhance the meaningful learning and student’s capability in solving problem of biology content.

1. Introduction

The ability to think can be classified into simple and complex thought skills [1]. The basic thinking process provides a summary of the process of critical thought which provides a collection of simple to complex mental processes. Model thinking skills include cause, transform, connect, classify and qualify. The ability to think based on logical thought is the abstract thinking capacity or the higher-order thinking. Costa claimed that at least four people have higher thinking skills, which are problem-solving, decision-making, critical thinking, and creative thinking. The higher level of thought skills built in this research is problem solving skills [1].

Problem solving ensures that prior knowledge can be applied in new circumstances. As a consequence, students would be able to solve similar or different problems very well. Teaching students to solve problems analytically helps them to take decisions in life.

Science, technology, engineering, and mathematics (STEM) is the latest trend issue in education. STEM is a methodology focused on a mixture of different disciplines, including science, technology, engineering and mathematics. The collaboration developed through STEM learning will assist students in gathering, analyzing and solving problems and understanding the connection between one problem and another [2].
The role of the instructor is about to nurture students’ skill in solving problems through selecting appropriate contents [3]. Teachers should discover issues related to technology that are important in their everyday lives, and then ask students, using the technical definition individually or with teacher guidance, to creatively overcome problems [4]. One of the lessons that allow the teacher to connect material and technology with their use in everyday life is through the use of science, technology, engineering and mathematics (STEM). So, STEM can be a platform to enhance this skills and primarily implemented in the context of human life.

Previous study indicated that students' critical thinking capabilities in plant and animal reproduction learning concepts were substantially higher through the implementation of integrated STEM learning [5]. STEM research increases understanding of science concepts considerably by students [6][7]. Students also better understand the idea of chemical balance [8]. After studying the content using STEM methods, students are more inspired to do research in chemistry course. They explored how science and technology relate to society and guide them to improve their abilities [9][10]. This lesson also reflects ideas for students to define, evaluate and find solutions to everyday problems [11][12].

The STEM approach is typically accompanied by active learning. STEM methodology can also be combined with PjBL (Project-Based Learning). PjBL is a learning model that uses projects/activities to develop competences, expertise and skills as a learning mechanism. The student's activities in producing the products is by applying their skills to study, evaluate, develop and present learning products based on real experiences. Besides, PjBL drives to acquire new information and learning skills, increase students' capacity to problem solve, increase the participation of students in the solution of complex problems by creating goods or services, and to grow and enhance their abilities in the management of learning resources, learning materials and tools to complete tasks/projects [13].

The learning steps in PjBL model as developed by the George Lucas Educational Foundation (Figure 1) consists of essential questions, project plan preparation, schedule arrangement, students’ activities monitoring, result assessment, and experience evaluation [14].

![Figure 1. The learning steps of PjBL model George Lucas Education Foundation.](image)

Integrated PjBL STEM learning will develop the capacity to solve problems and help students achieve fun learning experiences and passion [15]. PjBL integrated STEM learning will enable students to answer difficult questions and focus on solving complex problems [16]. Besides, previous research found that integrated STEM learning by PjBL is genuinely meaningful, helping students overcome real-life challenges and encouraging future careers [17]. Integrated STEM learning from PjBL offers opportunities and motivates students to practice critical thought and evaluate to promote higher order thinking [18].

Based on visiting observation in SMAN 1 Darul Imarah and SMAN 5 high schools, the participation and interest in learning of students in the content of the immune system are poor. It is evaluated that the immune system topic is hard to understand. This topic is also complex and gives students multiple opinions. Then, to overcome this problem, an alternative solution selected is to implement STEM-Integrated learning in the PjBL model. Theoretically, this learning approach is predicted as a potential way to enhance students’ ability to think and solve problems.
Therefore, the researchers decided to carry out a research to answer following question: Is there any improvement of the problem-solving capacity of students through the implementation of STEM approach combined with PjBL on immune system concept?

2. Methods
This study has been conducted in the 11th grade of SMAN 5 Banda Aceh and SMAN 1 Darul Imarah Aceh Besar. This study employed a quasi-experimental pre-test design with a non-randomized control group. All the students of 11th grade at SMAN 5 Kota Banda Aceh and SMAN 1 Darul Imarah Aceh Besar were the population. While the sampling technique was a purposive sampling technique that considered the following requirements: the school is accredited A, the students have moderate skills, and the school is located near the town. Each class selected was decided to an experimental and control class, as illustrated in Table 1.

| No | School               | The Quantity of Student | Treatment | Control Class |
|----|----------------------|-------------------------|-----------|---------------|
| 1  | SMAN 1 Darul Imarah  | 38 students             | XI IPA 1  | XI IPA 3      |
|    |                      |                         | (grade 11<sup>th</sup> Science Class 1) | (grade 11<sup>th</sup> Science Class 3) |
| 2  | SMAN 5 Banda Aceh    | 44 students             | XI IPA 4  | XI IPA 1      |
|    |                      |                         | (grade 11<sup>th</sup> Science Class 4) | (grade 11<sup>th</sup> Science Class 1) |

A solving problem test (attached inside the learning module) was used to assess students' ability in understanding immune system concepts in the student worksheet. The test was conducted to determine the ability of students to solve problems after the PjBL integrated STEM worksheet was implemented. The data analysis of the validation results used validation according to Aiken V. The value of the module content validity coefficient was more than 0.69, which indicated as valid criteria and could be used in this study. Data from student evaluation of problem-solving abilities were processed and descriptively analyzed by calculating the average score from the test results.

3. Results and Discussion

3.1. Results
The results of the problem-solving ability of students in the experimental class and control class at SMAN 5 Banda Aceh and SMAN 1 Darul Imarah showed in Figure 2.

Figure 2 shows the problem-solving ability of students in each aspect of the question is different. The problem-solving ability score data is read based on the categories proposed by Arikunto [18]. The average score of problem-identification skills having by students in SMAN 1 Darul Imarah and SMAN 5 Banda Aceh SMAN 1 Darul Imarah was 94 and 85 respectively. It indicated that both schools have a very good category, which is capable to identify related problems. For the problem formulation indicator, SMAN 1 Darul Imarah has an average score of 81 and a score of 85 in SMAN 5 Banda Aceh. Both schools have an outstanding category. This result indicated that the two schools are having similar level of formulating problems.

The graph also shows that both schools have very good category level of ideas formulation in solving the problem. The scores of ideas formulation in problem solving were 100 and 90 for SMAN 1 Darul Imarah and SMAN 5 Banda Aceh respectively. In addition, for the aspect of creating the best solution, SMAN 1 Darul Imarah has an average score of 100 and SMAN 5 Banda Aceh got average score of 95. This shows that the two schools have the ability to create the best solutions that are not much different or the same (very good category).

Lastly, in the aspect of evaluating the solution, SMAN 1 Darul Imarah has an average value of 81 (very good category) and SMAN 5 Banda Aceh has average score of 70 (good category). Those scores indicated that the two schools have the ability to evaluate solutions at a similar level. In general,
students from both schools have problem-solving abilities that are not much different or in the same category level.

![Graph of Average score of Student’s Problem-Solving Ability in Experiment Class and Control Class in SMAN 5 Banda Aceh and SMAN 1 Darul Imarah.](image)

**Figure 2.** Graph of Average score of Student’s Problem-Solving Ability in Experiment Class and Control Class in SMAN 5 Banda Aceh and SMAN 1 Darul Imarah.

### 3.2. Discussions

The positive effects cannot be separated from the student learning process. In this study, researchers found that students were very happy with their student worksheets which combined STEM learning based PjBL, since students had problems in real life and were challenged to solve those problems. Students are inspired to learn and constructively solve problems. Students should work to define problems, to formulate problems, to find ideas for troubleshooting, to find the best solutions and evaluate solutions. At the end of the lesson, students will then find answers to their problems. The integration of STEM, STEM combined PjBL, and or the application of PjBL based learning to improve student’s ability in solving problem has also found giving significant result in previous studies [20][21][22][23][24].

The students' project in this study was to create antivirus disinfectant spray. In classes, students learn the content from the student worksheet. Student worksheets intended to guide students in learning by creating groups and students are expected to discuss the steps of preparing the worksheet. This method of learning increases students’ interest in science studies.

| No. | Aspects     | Activities                                                                 |
|-----|-------------|-----------------------------------------------------------------------------|
| 1   | Science     | - Formulating problem by reading the immune system material                |
|     |             | - Getting and applying the information gathered to solve the problems     |
| 2   | Technology  | - using smartphone                                                         |
|     |             | - using the internet                                                       |
|     |             | - calculating using Ms Excel                                               |
| 3   | Engineering | - processing the Nutmeg essential oil                                      |
| 4   | Mathematics | - Making a serial mixture of solutions with the concept of ratio and volume |

Besides a realistic guide, the PjBL-integrated STEM worksheet is designed to help students find a definition. Apriyani stated that STEM approach could trained students in asking questions and
defining problem stages of the PjBL based on their daily life issues [20]. Students are bored only with the process of lecturer and the most difficult to grasp the idea of the subject of science. With the STEM-based worksheet, students face real-life challenges, and they will be challenged to find answers to problems and to build their answers. In this lesson, students are led to make products to protect themselves from diseases every day. The ingredients are natural ingredients of local wisdom and other natural ingredients that contain no chemical elements that threaten our body's health. When implementing student worksheets with PjBL integrated STEM learning, collaboration can be seen on these four STEM aspects. Table 1 indicates the stages of the STEM project.

The science aspect appears in the process of formulating issues based on the debate in the student's workbook, meaning that the science aspect emerges when the knowledge they gathered to solve problems in the student workbook is collected and implemented. Students use the technical element to find solutions for problem-solving, and students use existing technology, such as smartphones and the Internet to facilitate the learning process. The technical aspect is present in the essential oil processing of the Nutmeg which is used as antivirus and applied to the produced product. The manufacture of nutmeg oil is performed by a complex distillation process used in the manufacturing of hand-sanitary products and antiviral spray. Besides, the element of mathematics occurs in the solution volume measurement, which is applied while mixing the solution. The solution volume must be used in conjunction with the dose so that the substance is delivered as intended.

The four disciplines collaborate with the student's corporate immune system worksheet which enables students to collect, analyze and solve issues and to understand the connection between one problem and the other. It also allows students to make enjoyable learning opportunities and encourages students to learn with enthusiasm. This condition indicates that integrated PJBL STEM learning with the students' immune system worksheet is used more efficiently in the learning process.

The products are developed by students after researching antiviral disinfectant spray and natural hand sanitization. Antivirus disinfectant spray is a product that can be manufactured from ingredients that are readily accessible by itself. This substance is made of non-health-destroying ingredients and is an antiviral agent of natural essential oils. This product is also made with natural hand sanitizing items that are clean, organic, easy to obtain and contain local wisdom values. Also, the ingredients can be conveniently purchased and safely used.

4. Conclusions
The use of the Science, Technology, Engineering and Mathematics (STEM) approach in a project-based learning (PjBL) model of immune system content is focused on testing, allowing students to develop their problem-solving skills. The combination of several learning strategies should have been applied by teachers to improve students learning outcomes.

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