Student’s STEM Literacy in Biotechnology Learning at Junior High School

N Nurlaely1,2*, A Permanasari1 and R Riandi1
1Sekolah Pascasarjana Universitas Pendidikan Indonesia, Bandung, Indonesia
2SMPN 3 Sodonghilir, Tasikmalaya, Indonesia
*nui.nelly.nui@gmail.com

Abstract. A considerable study to student’s STEM literacy achievement profile, especially in biotechnology learning, has been conducted to make the innovation of the STEM-based learning. The study aims to find out the STEM literacy. The sample is taken through purposive sampling technique to 45 students of 9th grade of a junior high school in Tasikmalaya district. The instruments are multiple choice questions. Data are analysed by calculating mean score of students’ STEM literacy achievement. The results show that student’s STEM literacy achievement was low. Science literacy aspect was the lowest, while mathematical literacy gained better than another aspect. The low achievement of students’ STEM literacy was because of learning activities that have not been able to integrate science, technology, engineering, and mathematics in science learning. The literacy profile indicates the importance of applying STEM approach to science learning, and it is recommended to improve students’ STEM literacy achievement.

1. Introduction

STEM education is an interdisciplinary approach to learning, where students use science, technology, engineering, and mathematics in the real context that connects schools, community, work, and the global world to develop STEM literacy [1]. Teachers can develop, apply, and support STEM literacy in the classroom learning by concerning three aspects. Firstly, Science, Technology, Engineering, Mathematics should not be seen as separated contents. Secondly, personal, social, and economic needs. Thirdly, domains of cognitive, affective/attitude, and psychomotor [2]. Eventually, this STEM literacy will make students being able to compete in a new economic era which is based on knowledge. Besides that, they are also trained to understand the complex issues so that they can find creative solutions. However, the separation of STEM literacy aspects particularly in computing the test results is needed to identify the weak points of students on each aspect of literacy.

Biotechnology constitutes a scientific study in science and technology which experiences rapid growth in recent years. Biotechnology can be applied in various fields and has social, ethical and economic implications in the form of risks and benefits for human life and the environment. Considering the impact of biotechnology on food, health, agriculture and the environment is very important; therefore, learning biotechnology in the school environment is needed for students as the sufficient provisions of scientific knowledge in developing a better understanding of the world around them [3]. Biotechnology (especially food biotechnology) is one of science materials in secondary school, which contains STEM. Besides, the material is closed to students' daily life, especially the present of technology that makes students easier to access information related to biotechnology.
Based on those findings, there is a need to conduct a research to determine the profile of students’ STEM literacy. The aim of the study is to get the picture of STEM literacy mastery, particularly related to knowledge, competencies on the topic of biotechnology. The results of the study can be used as the guidelines in selecting suitable model or strategy in the implementation of science learning with the integration to STEM.

2. Experimental Method

The method that used in this research was the descriptive method. It was used for determining profiles of students’ mastery in STEM literacy without any treatment previously. The design of the research can be seen in Figure 1.

![Experimental Method Diagram]

Figure 1. Research design

The sample was 45 students of grade 9 (nine) in one of the junior high schools in Tasikmalaya district. The sampling technique used in this study was purposive sampling because cluster group has been formed in school and there was zero change by the researcher. The sample selection was based on particular purpose [4], which is because students have been trained in the biotechnology topic.

The instruments used in this research were 24 multiple choice questions, consisting of 10 questions on science literacy, 8 questions on technology engineering literacy, and 6 questions on mathematic literacy problems. The scientific and mathematical literacy problems were developed using indicators which were developed by PISA 2015 [5], while technological and engineering literacy was developed using indicators which were developed by NAEP 2014 [6]. The indicators are described in Table 1.

| No | STEM Literacy Component | Indicator                                                                 | Number Question |
|----|-------------------------|---------------------------------------------------------------------------|-----------------|
| 1  | Science                 | Explain phenomena scientifically                                            | 1, 2, 3, 6, 20, 21 |
|    |                         | Evaluate and design scientific enquiry                                     | 22, 15          |
|    |                         | Interpret data and evidence scientifically                                 | 14, 23          |
| 2  | Mathematics             | Formulating situations mathematically                                       | 8, 9, 18, 19    |
|    |                         | Evaluate and design scientific enquiry                                     | 16, 17          |
| 3  | Technology Engineering  | Understanding technological principles                                     | 5, 10, 11, 13   |
|    |                         | Developing solutions and achieving goals                                   | 4, 7, 12, 24    |

An instrument is said to be valid and reliable when it is able to measure what will be measured and can reveal data from the variables studied consistently. In this study, the validity testing was performed by the validator experts consisting of five people who are experts in the field of STEM, assessment, and biotechnology content. The validation process resulted in content validation index (CVI) of 0.907 using $\text{CVR}_{\text{critical}} = 0.877$ on the level of $\alpha = 0.05$. Reliability analysis using Cronbach’s alpha was processed using SPSS 20 resulted in the reliability value = 0.786. The results of test scores show appropriated validity and reliability [7].

The questions were tested on the sample to see the achievement of student literacy on score using the formula:
The scores achieved were analyzed using descriptive statistics to find the mean, standard deviation, maximum and minimum score. Descriptive statistical analysis was also performed on each STEM literacy component of the students, i.e. science, engineering technology, and mathematics.

3. Result and Discussion

The results of this study were obtained through descriptive statistical analysis showing the achievement of STEM literacy as a whole and the achievement score of each STEM literacy component. The ideal achievement score is 100. The results show that the average STEM student literacy score is still low (55.28). The average profile of STEM literacy achievement of students can be seen in Table 2.

| STEM Literacy Component | N  | Ideal Score | Minimum | Maximum | Mean | Std. Deviation |
|-------------------------|----|-------------|---------|---------|------|---------------|
| Science                 | 45 | 100         | 20.00   | 90.00   | 49.56| 20.775        |
| Technology Engineering  | 45 | 100         | 0.00    | 100.00  | 55.28| 26.178        |
| Mathematics             | 45 | 100         | 16.67   | 100.00  | 64.82| 19.209        |
| STEM Literacy           | 45 | 100         | 25.00   | 87.50   | 55.28| 18.621        |

The students are not customized to undertake the test which contains the four aspects of STEM. Moreover, students get used to the test items which require memorization, so that students got difficulty in doing the questions with casuistic characteristic and involves the integration of science, technology, engineering, and mathematics for the solution. Examples of casuistic problems in tests can be seen in Figure 2.

To answer questions 6 to 8, please read the following text.

Today, my Mom makes fermented glutinous rice. The necessary ingredients consist of glutinous rice, yeast, and water. The process of cooking is simple, but it must pay attention to the cleanliness of tools and materials. For 1 kg of glutinous rice, my Mom uses 4 yeast blocks of 4 grams. The steps of making fermented glutinous rice are as follows:

a. Soak glutinous rice for 12 hours
b. Wash the glutinous rice cleanly that has been soaked
c. Steam the glutinous rice till cooked and cool it down
d. Once getting cold, sprinkle the glutinous rice with yeast, and then mix evenly
e. Put the glutinous rice into the closed place or wrap it up with guava leaf for 3-4 days.

6. Microorganisms used in making of fermented glutinous rice are at
   a) water     b) yeast      c) guava leaf     d) glutinous rice

7. In the step of making the fermented glutinous rice, the step which is based on the principle of biotechnology is...
   a) using yeast b) steaming glutinous rice c) soaking glutinous rice all night long d) keeping cleanliness tool and ingredients

8. What is the ratio of yeast and ingredient that must be fulfilled to make fermented glutinous rice?
   a) 1 : 25     b) 1 : 250     c) 25 : 1     d) 250 : 1

Figure 2. Example of question for student STEM literacy

The question no. 6 in Figure 2 shows a scientific literacy question that is expected to develop competence to “explain phenomena scientifically”. Students who have achieved the competence to
“Explain phenomena scientifically” will recall and apply appropriate scientific knowledge in their lives [5]. The question no. 7 trains students in “developing solutions and achieving goals”. When students have been able to select and use appropriate tools to achieve a goal, they will build their technology engineering literacy [6]. Development of mathematical literacy in “formulating situations mathematically” is illustrated in the question no. 8 which shows the ability to translate a problem into mathematical language or a representation [5].

The result of data analysis on each component of STEM literacy also shows low score achievement. Students achieved the highest achievement on the aspect of mathematical literacy (64.82%), while the lowest achievement was obtained in the science literacy aspect (49.56%). The low scientific literacy achievement was because students find it difficult to answer the questions required them to be able to develop a competence which is required in scientific literacy, i.e. “evaluate and design scientific inquiry”. Students who mastered these competencies will have the ability to propose a way of exploring a given question scientifically [5]. The questions that demonstrate this competence can be seen in Figure 3.

BREAD DOUGH
To make bread dough, the cook mixes flour, water, salt, and yeast. After mixing, the dough is stored in the container for several hours for the fermentation process. During fermentation, chemical changes occur in the dough: the yeast (unicellular fungi) will change the starch (carbohydrate) in the form of glucose in the flour into carbon dioxide and alcohol. A few hours after mixing the dough, the cook weighs and observes that the dough mass has been reduced. In the beginning, the dough mass is the same in each of the four trials shown below. Which two experiments should be compared by the cook to test that yeast is the cause of the dough’s reduced mass?

A. The cook should compare experiments 1 and 2.  C. The cook should compare experiments 2 and 4.
B. The cook should compare experiments 1 and 3.  D. The cook should compare experiments 3 and 4.

Adapted from the science literacy question of PISA 2015

Figure 3. Example of question for student STEM literacy in science content
Science literacy achievement of students should be the basic to master knowledge and overall STEM competency. Science literacy is essential to be mastered by students. It is related to how students can understand the environment, health, economic, and other problems in modern society who depends on a lot of technology and scientific knowledge. Furthermore, science literacy is a key to success in science education of students aged about 15 years old. If they succeed in learning science, so they can continuously learn it. But, if they fail, students will stop learning [8].

The results of interviews with teachers and students in the sample of this study indicate that the teaching methods applied in the classroom still use conventional methods that spend the time to learn the scientific concepts without giving the opportunity to construct their own knowledge. Students tend to be passive and the process of learning is only a transfer of knowledge from teacher to student without becoming a meaningful learning for students. As a result, science subject just becomes something difficult and unpleasant for students. Learning activities should be encouraged on research and question analysis/science problem analysis so that students can learn how to find solutions by using technology and arranging an experiment which can prove a science concept and it is supported by the data that are managed mathematically [9].

Science education has the important role in developing students’ STEM literacy. It is seen from the purposes of science learning which are improving the definition to the natural world so that students are able to understand and make decisions related to the environment, health, economic, and other problems faced by modern society who depends on technology, improvement, and outgrowth of science [10]. Therefore, it needs a learning model that is able to facilitate students in developing their STEM literacy. Application of the principles of design in science learning is required for the application of student knowledge into the real world and helps prepare students for continuing education to a higher level, and ultimately in the future students will be professional human beings in their field of work. One of the ways to accomplish is by tapping into project activities in learning through the STEM integrated project-based learning model [11].

The most appropriate model of teaching is the key to success in achieving better literacy achievement. Learning model needed in science learning is that can encourage learners to be able to solve problems in life both individually and in groups by applying knowledge and utilizing technology as a form of awareness and contribution to environmentally responsible quality improvement [12].

4. Conclusion
The result of the research showed that the achievement of students’ STEM literacy was low. The results of the study revealed the lowest achievement was on the aspect of science literacy. Low achievement students’ STEM literacy implied the need of innovation in science learning which can cope with the limitation of students thus far. Based on the results and review of the literature, it is recommended an innovation of STEM-based learning with Project-Based Learning (PjBL) Model. This model theoretically can improve skill/competency domain that has been a major weakness so far. The use of STEM with PjBL model in learning science is highly recommended to increase students’ STEM literacy achievement.

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