The analysis of product outcome of STEM (Science, Technology, Engineering, and Mathematics) learning for prospective teachers of biology education in the industry 4.0

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Abstract. Particular specifications related to the present study are very important to be implemented out given the development of the Industry 4.0 which demands innovations in learning. The STEM project in learning--by combining science, technology, engineering and mathematics--becomes collaborative in order to overcome problems that often arise in the world of education, especially at the college level that produces teachers generally in schools. Prospective teacher students often experience difficulties in making papers that include STEM components in them. The purpose of this study is to analyze STEM learning that enables students to make better products than other students who obtain regular learning. This study was designed as a quasi-experimental study. The research design was a static group comparison involving at least two groups. The product of STEM results were taken from the students of Biology Education of 2019-2020 Class A consisting of 21 students and Class B consisting of 21 students. Prospective teacher students often experience difficulties in making papers that include STEM components in them. The data analysis used was the product data analysis. Each of the descriptive statistics was analyzed, then inferential statistics were analyzed to see the significance of each class. The conclusion obtained is the ability of students who get STEM learning in writing papers is better than students who get regular learning.

1. Introduction

Prospective biology teacher students have an obligation within themselves to carry out scientific programs such as making several products such as written works. Prospective teacher students generally have a relatively low ability to make a variety of products. The STEM approach which has four substantial components is expected to improve the ability of prospective teacher students to create and develop scientific writing products. STEM has many definitions according to each expert, STEM is a learning that combines the integration of the four aspects of scientific knowledge that consists of Science, Technology, Engineering and Mathematics [1]. These four aspects can be defined as each of the knowledge such as: 1) Science: A systematic study of the nature and behavior of the material and physical universe, based on observations, experiments, and measurements, and the formulation of laws...
to describe facts in general. 2) Technology: A branch of knowledge relating to the creation and utilization of technical facilities and their relations to life, society and environment, utilizing subjects such as industrial arts, engineering arts, applied science, and pure science. 3) Engineering: the art or science of creating practical applications of pure science knowledge, such as physics or chemistry, as in the construction of machinery, bridges, buildings, mines, ships, and chemical plants. 4) Mathematics: A group of sciences including algebra, geometry, and calculus, which deals with the study of numbers, numbers, shapes, and spaces and their interrelations by using special notations.

Based on the result of a preliminary study conducted by the author to 10 lecturers in the Biology Education study program related to: 1) the collaborative use of STEM learning (science, technology, engineering and mathematics) in teaching shows that 70% of lecturers have not fully taught STEM collaboratively, only some of them use learning animations, some lecturers use the methods of discussion and presentation methods and strategies in teaching as well; 2) related to the knowledge of lecturers about STEM learning shows that almost 100% of them know it as a learning trend but they have not known how it is implemented in learning; 3) related to the research of the lecturers in using technology, it shows that almost 70% of the lecturers have used technology in learning, such as blended learning, learning animation, learning video, virtual lab, interactive multimedia; 4) related to the knowledge of the studies they are conducting shows that almost 100% of them conduct studies on computational frameworks, implementations and results.

This ongoing project contributes to build up the project by combining science, technology, engineering and mathematics becomes collaborative in order to overcome the problems that often arise in the world of education, particularly at the college level, that produces teachers generally in schools. In relation to technology, "The utilization of e-learning (technology), aside from an effort to overcome the technical problems of learning (learning media), is also as an effort to answer the problems of substantial learning (teaching resources)" [4].

The BTEM (Biology, Technology, Engineering, and Mathematics) interdisciplinary approach is an alternative conceptual framework applied in contexts to deal with changes in Biology of 21st century, is able to foster students' abilities to engage in scientific inquiries and discover their own biological contents [5]. STEM (Science, Technology, Engineering, and Mathematics) emphasizes that being more involved in a scientific inquiry requires the coordination of knowledge and skills simultaneously. The result of the study also shows that STEM increases students' abilities to build their own knowledge through activities that are directly related to thoughts and emphasis on scientific practices.

The use of computers with STEM thinking is able to increase the computational-based thinking strategy that is adopted to enforce STEM-based computationally thinking [6]. STEM presents frameworks, implementations and results. This ongoing project contributes to build computational thinking as an attitude that can be applied universally that is put together in discussions, education, and STEM curriculum.

The term STEM was first used by the NSF (National Science Foundation) in the 1990s as an acronym for science, technology, engineering and mathematics. Initially, the first acronym proposed was SMET but this acronym had a negative connotation with the word ‘smut’. Then, the acronym METS was proposed, but this acronym also received less response from the NSF members because some said that this was the name of a national baseball group in New York. Finally, the STEM acronym emerged and
all members agreed because it had a lot of positive correlations with fields related to the National Science Education Standard [7] STEM in educational context.

2. Method
This study was designed as a quasi-experimental study. The research design was a static group comparison involving at least two groups. The STEM products were taken from Class A of Biology Education students consisting of 21 people and Class B consisting of 21 people. The static group comparison was also called the post-test-only design with the non-equivalent group, namely Group 1 receiving interventions or treatments before the dependent variables were measured, while the second group did not receive the interventions or treatments [8].

| Treatment | Posttest |
|-----------|----------|
| X1        | O1       |
| X2        | O2       |

The STEM learning is partly done outside the classroom, namely in the laboratory, because Learning using the Outdoor Learning method has strengths, such as, 1) with variative learning, students will have fresh thinking because of the changes of atmosphere, 2) inquiries are more productive, 3) acceleration is more integrated and spontaneous, 4) exploration ability is more coherent, and 4) fostering reinforcement of concepts. Moreover, learning using ICT has a positive influence. utilization of e-learning in mathematics has positive influences. Other than as an effort in solving technical problems as learning media, this can also be an effort to address substantial learning problems as learning material [9]. The data analysis used was the product data analysis. Each of the descriptive statistics was analyzed, then inferential statistics were analyzed to see the significance of each class.

3. Results and Discussion

3.1. The Analysis of STEM Learning Products in the Subject of Anatomy and Physiology Anatomy and Physiology of the Human Body (Anfistuman)
There was a product data analysis taken from Biology Education students related to the paper writing in the Anfistuman subject. Class A obtained the STEM learning model and Class B received regular learning. Regular learning consists of the presentation of written information without being associated with the STEM approach in the writing process. The analyzed data were categorized into 5 components including: (1) Systematics (table of contents, foreword, literature, glossary, and index), (2) Attractiveness (layout, coloration, harmony), (3) clarity of information(readable, well-structured), (4) Substance (objectives, methods, results), and (5) Total score.
Table 2. The Descriptive Statistics of the Assessment of the Students’ Products

| Descriptives                      | Class A |           | Class B |           |
|-----------------------------------|---------|-----------|---------|-----------|
|                                   | Statistic | Std. Error | Statistic | Std. Error |
| Mean                              | 2.8587   | .08439    | 2.9881   | .01190    |
| Variance                          | .164     |           | .003     |           |
| Std. Deviation                    | .40470   |           | .5455    |           |
| Minimum                           | 2.00     |           | 2.75     |           |
| Maximum                           | 4.00     |           | 3.00     |           |
| Range                             | 2.00     |           | .25      |           |
| Mean                              | 2.3810   | .06818    | 2.8587   | .08439    |
| Variance                          | .098     |           | .164     |           |
| Std. Deviation                    | .31244   |           | .40470   |           |
| Minimum                           | 2.00     |           | 2.00     |           |
| Maximum                           | 4.00     |           | 2.00     |           |
| Range                             | 2.00     |           | .25      |           |
| Mean                              | 2.3810   | .06818    | 2.8587   | .08439    |
| Variance                          | .098     |           | .164     |           |
| Std. Deviation                    | .31244   |           | .40470   |           |
| Minimum                           | 2.00     |           | 2.00     |           |
| Maximum                           | 4.00     |           | 2.00     |           |
| Range                             | 2.00     |           | .25      |           |
| Mean                              | 2.3810   | .06818    | 11.5761  | .25316    |
| Variance                          | .098     |           | 1.474    |           |
| Std. Deviation                    | .31244   |           | .12141   |           |
| Minimum                           | 9.00     |           | 9.00     |           |
| Maximum                           | 15.00    |           | 6.00     |           |
| Range                             | 6.00     |           | 3.25     |           |

Attractiveness is constant when Class = Class A. It will be included in any boxplots produced but other output will be omitted.
In Table 3, the significance value is 0.00 < 0.05 so that $H_a$ is accepted, that there are significant differences in the students' abilities in paper writing. To see which class is better, here are the results of the analysis:

**Table 3.** The Comparative Analysis of Total Data of Information between the Classes

| Ranks       | Class | N  | Mean Rank | Sum of Ranks |
|-------------|-------|----|-----------|--------------|
| Class       |       |    |           |              |
| A           | 21    | 29.39 | 676.00    |
| B           | 21    | 14.95 | 314.00    |
| Total       | 42    | 2   |           |              |

In Table 3, the mean rank of Class A is greater than Class B’s, meaning that the ability of Class A students in making papers products is better than Class B students. It indicated that the abilities of students who get STEM learning in making biotechnology products is better than the abilities of students who get regular learning.

### 3.2. Discussion

The STEM learning, which is an integrated learning from four different scientific knowledge such as science, technology, engineering and mathematics, emphasizes learning in a scientific, technological-assisted systematic manner without eliminating the beauty of products made. The assessment of STEM learning products in the *Anfistuman* subject consists of four aspects, namely 1) the systematics of writing, 2) the attractiveness of writing, 3) clarity of information presented and 4) the substance of the paper. From a total of 42 Biology education students consisting of two classes, it can be seen that STEM learning outcomes in class A have better grades compared to class B’s as presented in the following figure:

![Figure 1. The Comparison of Analysis Results of STEM Learning Outcomes in Prospective Teachers](image)

The systematics of writing in class A has a the value of dominance with a range of values that is quite good compared to class B’s. Reports collected in Class A have better completeness and are organized between one sub-chapter and the next one. In class B, the majority of grades are still in the inadequate category, namely the reports are still incomplete with the organization in each sub-chapter having poor conformity. The acquisition of grades in class A shows that STEM learning can significantly help students' abilities in compiling systematics of paper writing. The STEM learning approach can directly enhance students' critical thinking skills, a systematic way of thinking makes students able to read and write papers systematically, for STEM is an interdisciplinary learning approach that involves students
in scientific learning [10]. This is also supported by a study that the STEM learning approach can have an impact on scientific processes and students’ attitudes so that the students can improve science process skills which also have an impact on learning attitudes in writing papers which prioritize writing systematics [11]. The use of language in writing as well becomes its own aspect that must be considered, namely the use of language that is not too rigid, and the use of images and tables that can support the reader to be more interested when reading. A study shows that the STEM learning approach can improve the positive impact of students in using language strategy developed in a paper, so that it can effectively improve the use of language that is more understandable by readers in the composition of the paper [12]. The clarity of information on paper writing is related to several things, including elaboration of information and structure of presentation when describing information to be presented in a paper. Authors must be able to put explanatory sentences in certain structures to facilitate readers. One of the roles of the STEM learning approach is that it starts from providing information to students that can have an impact on students becoming more observant and detailed in providing information in a paper [13]. The substance of paper writing that includes the main content, material and elements is the core of scientific writing. These four aspects which consists of systematic, attraction, clarity of information and the substance of the paper can be significantly improved by the teachers using the STEM learning approach.

4. Conclusion
From the results of the study obtained, there are several things that can be concluded relating to the analysis of STEM learning outcomes of prospective biology teachers, namely: 1) The STEM learning approach (Science, Technology, Engineering and Mathematics) can help students in writing their systematic scientific paper writing of because there are elements of scientific approach in STEM learning requiring students to write in structured and systematic manners. 2) The attractiveness of scientific paper writing becomes the aspect with the highest value acquisition. The students of prospective Biology teachers have describing every sub-main concept in the writing systematics, the use of interesting tables is also an added value of the attractiveness of the scientific papers they write. 3) The aspect of clarity of information and the substance of the paper become the main focuses of students in presenting scientific papers, so that STEM emphasizes a scientific approach, science process skills also help significantly in writing information and content in the paper. 4) Generally, the STEM learning approach (Science, Technology, Engineering and Mathematics) can significantly help the students of prospective teachers in making scientific papers with aspects that can accommodate the Industry 4.0.

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