Smartphone microscope based on the STEM approach as a practicum tool to improve students' scientific attitudes on Animalia

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Abstract. This study aims to determine the scientific attitude and its relationship to the student learning outcomes of Animalia using a smartphone microscope based on the STEM approach as a practicum tool. This research is a quantitative approach using a quasi-experimental (Pretest-Posttest Non-Equivalent Control Group Design) and descriptive method. The scientific attitude was measured by the observation sheet and multiple-choice tests (pretest-posttest) to measure the learning outcomes. The study population was all Year 10 students at SMAN 1 Woyla, Aceh, Indonesia. The samples, class X MIA1, and X MIA2, were chosen using the purposive sampling technique. Data of scientific attitudes were analyzed using quantitative descriptive through the percentage formula, and correlation and regression tests were conducted to analyze the relation between scientific attitudes and learning outcomes. The results showed that the scientific attitudes of the two classes were in the very high category (experimental class: 94.8%, control class: 95.1%). The results of the correlation test of scientific attitudes towards learning outcomes revealed $r_{\text{count}} > r_{\text{table}}$, indicating a positive effect. The regression test results showed the $R^2$ of 0.120, indicating that scientific attitudes explained the variance of learning outcomes by 12.0%.

1. Introduction

Education today requires students to have various skills to compete in the 21st century. Graduates need not only cognitive competence but also a good attitude. Nowadays, the competency needs in the labor market include the cognitive, affective, and psychomotor domains. These three domains cannot be separated. Article 25 (4) of Government Regulation Number 13, 2015, concerning National Education Standards explained that graduates' competence includes attitudes, knowledge, and skills [1]. This is also emphasized in the 2013 curriculum (K-13), the current education curriculum in Indonesia, where K-13 serves as a guide for the implementation of three domains of learning activities: attitudes, knowledge, and skills [2].

Indonesia has gradually applied the Curriculum 2013 (K-13) for six years. However, not all schools have implemented it. The Ministry of Education has only made it mandatory for all schools in the 2018/2019 academic year [3]. However, not all teachers in schools have performed the curriculum in accordance with the objective of K-13. Teachers tend to improve the cognitive domain, but the affective domain is rarely developed [3]. This may be due to incompetent teachers, the difficulties in developing the affective assessment instruments, and teachers assuming that the affective domain is not as important as the cognitive domain. This is in line with Fatonah [4] who argued that learning objectives had not been fully manifested in schools, as in K-13 and Bloom's Taxonomy, are cognitive, affective, and...
psychomotor aspects. In other words, schools only emphasize on the cognitive aspect and overlook others.

One aspect of the affective domain is the scientific attitude. It is crucial to develop this aspect because it is a form of intelligence in every individual. With a scientific attitude, it can train students to form a systematic mindset so that they can solve problems. According to Fakhruddin et al. [5], students' scientific attitudes in learning can affect the learning outcomes, including science class subjects, such as biology. However, referring to previous statement, teachers pay less attention to the scientific attitudes in the aspect of affective. The findings of Rahman [6] at SMP Negeri 1 Danau Kembar, Solok Regency, Indonesia showed that students' scientific attitude is still low, especially the ability to ask questions and carry out scientific experiments or practices. Because the methods applied are generally lecture methods and practice questions. Pertwi. et al. [7] also explained that one of the current problems in practicum is that many focus in the technical aspects of experiments and tend to ignore the substance of an experiment, resulting in the scientific attitude aspect to not develop properly. On the other hand, scientific attitude is commonly developed in science.

One way to improve a scientific attitude is to do learning with practical methods through active, innovative, and constructive learning models. The examples of constructivism learning include the science, technology, engineering, and mathematics (STEM) approach. Tsuropos et al. [8] suggested that STEM involves students using science, technology, engineering, and mathematics in real contexts. It can also train students' scientific attitudes, support the learning outcomes, and create products to support a more advanced life and answer the 21st century's challenges.

An innovative product that can be developed to train students' skills and scientific attitudes is the smartphone microscope. It can improve scientific attitudes through practicum by observing animal characteristics on the topic of Animalia.

Based on the observations at SMAN 1 Woyla, Aceh, Indonesia, it was found that the biology teachers thought they did not improve students' scientific attitudes on the topic of Animalia. Teachers generally focus on improving the cognitive aspect with a conventional learning method. The interview results showed that the teachers have never trained, developed, and evaluated the students' scientific attitudes. They were lacking in designing instruments and developing creative learning tools. Students did not get direct learning experiences, such as learning through a practicum. Also, teachers have never used the STEM approach. Thus, this study aims to determine scientific attitudes and analyze their relationship to student learning outcomes on the topic of Animalia using a smartphone microscope based on the STEM approach.

2. Literature Review

2.1 Smartphone Microscope

The smartphone microscope was invented by Kenji Yoshino, using readily available items and a smartphone [9]. The tools and materials used consist of easy-to-find tools and materials, such as electric drills/manual drills, rulers, cutters/knives, markers, acrylic/plastic glass, bolts, and nuts measuring 10, toy lasers, thick plywood, and tape [10]. The smartphone microscope, according to Agustina [9], also has advantages and disadvantages. The advantages are: (a) it can be practiced directly; (b) it can use a smartphone to observe the object; (c) the students can have a better learning experience; (d) it can attract and maintain the attention of students well; (e) it can observe the results directly with the smartphone. Meanwhile, the disadvantages are: (a) It requires a smartphone that has a camera; (b) simpler observations; (c) need to find tools and materials to make a microscope. Students design this smartphone microscope by applying the STEM approach presented in the student worksheet.

2.2 STEM (Sains, Technology, Engineering, and Mathematics)

STEM is an acronym for the fields of science, technology, engineering, and mathematics. STEM education was originally called science, mathematics, engineering, and technology (SMET) [11]. Becker and Park [12] explained that STEM education is an approach for teaching and learning between two or
more STEM components or between one STEM component and other disciplines. Meanwhile, Revere and Avery [13] stated that STEM education is an interdisciplinary approach, in which students are required to have knowledge and skills in the fields of science, technology, and engineering. There are three approaches to implement STEM learning by Robert and Cantu [14], namely a separate approach (silo), embedded approach (embedded), and integrated approach. STEM learning also has five stages in its implementation, including observation, new ideas, innovation, creativity, and society [15]. The STEM approach was not applied entirely in this study, but it was only applied to the process of creating a smartphone microscope following the design loop. While, the overall approach used was a scientific approach.

2.3 Practicum
Practicum is a form of the learning activity that aims to strengthen students' knowledge of subject matter through application, analysis, synthesis, and evaluation of theory, which is carried out both in the laboratory and in the field [16]. Practicum in biology learning is an effective method to achieve learning goals [17]. Practicum can also make students understand the concept and the nature of science as a process and products [18]. Practicum contains several functions, including finding facts in theory and developing skills in students. Students in the experimental class conducted the practicum to observe Animalia characteristics using a STEM-based smartphone microscope they have designed. Meanwhile, in the control class, the students used a light microscope available in the laboratory.

2.4 Scientific Attitude
The scientific attitude is essentially the attitude shown by scientists when carrying out an activity as a scientist. A scientific attitude is an attitude that must be present in a scientist or academician when facing scientific problems. It will be obtained through experience, learning activities, identification, and role behavior (educator-student, parent-child) [19]. Bundu [20] has categorized completely included those proposed by three experts: Gega, Harlen, and AAAS (American Association for Advancement of Science).

| Table 1. Classification of scientific attitudes [20]. |
|--------------------------------------------------|
| **Harlen (1996)** | **Gega (1997)** | **AAAS (1993)** |
| a. Curiosity | f. Open-minded | a. Curiosity |
| b. Respect for evidence | g. Cooperation with others | b. Inventiveness |
| c. Critical reflection | h. Willingness to tolerate | c. Critical thinking |
| d. Perseverance | i. Sensitivity to environment | d. Persistence |
| e. Creativity and inventiveness | | d. Skepticism |

The practicum activities using a smartphone microscope based on the STEM approach were conducted through the scientific approach steps and discovery learning model to observe the characteristics of the Animalia. This application is expected to improve scientific attitudes, including: curiosity, engagement, carefulness, honesty, discipline, and cooperative.

2.5 Animalia Topics
Animalia is taught at SMAN 1 Woyla in the first semester of Year 10. Generally, the material is about animals, which are classified into two groups: vertebrates and invertebrates. Vertebrates are Pisces, Amphibians, Reptiles, Aves, and Mammalia. Invertebrates animals consist of Protozoa, Porifera, Coelenterata, Platyhelminthes, Nemathelminthes, Annelida, Mollusca, Arthropoda, and Echinodermata [21].

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3. Research Methods

3.1 Context and Participation
The approach used is quantitative with the type of applied research. The method used a quasi-experiment (to determine the after-treatment effects of learning outcomes) and descriptive (to provide an overview of scientific attitudes). The design used a Pretest-Posttest Non-Equivalent Control Group Design (experiment: application of a smartphone microscope based on the STEM approach, control: application of a non-STEM light microscope). This research was conducted in class X MIA1 and X MIA2 at SMA Negeri 1 Woyla, Aceh Barat District, Aceh Province. The research time took place in the even semester of the 2019/2020 academic year. The sampling technique is purposive sampling. The sample details are as follows.

| Class   | Sample | Frequency |
|---------|--------|-----------|
|         | Male   | Female    |          |
| X MIA 1 | 8      | 21        | 29       |
| X MIA 2 | 11     | 18        | 29       |
| Total   | 19     | 39        | 58       |

3.2 Instrument
The instrument used to assess scientific attitudes is an observation sheet in the form of a rating scale accompanied by a rubric as an assessment guide. The indicators measured included the attitude of curiosity, active, rigorous, honest, disciplined, and cooperation developed from scientific attitudes, which are stated by Harlen, Gega, and AAAS.

3.3. Data Analysis
3.3.1. Scientific Attitude Data
The research data on the scientific attitudes of students during the practicum were analyzed using quantitative descriptive methods applying the percentage formula as follows:

\[
\text{Percentage} = \frac{\text{Score Obtained}}{\text{Maximum Score}} \times 100\% \quad [22]
\]

The analysis results of the scientific attitude towards the students is interpreted by the criteria shown in table 3.

| Score     | Description   |
|-----------|---------------|
| 86-100%   | Very high     |
| 76-85%    | High          |
| 60-75%    | Moderate      |
| 46-59%    | Low           |
| ≤ 45%     | Very low      |

3.3.2 The Correlation Data of Scientific Attitude on Learning Outcomes
Analysis of the correlation data between scientific attitudes towards learning outcomes used the Pearson product-moment correlation test (test r) to see whether there are a correlation and regression test (R square) and to see how much influence it has. This test used SPSS version 26.0 based on decision making if the value of \( r_{\text{count}} > r_{\text{table}} \), then it is correlated, and if \( r_{\text{count}} < r_{\text{table}} \), then it is uncorrelated [23]. The degree of correlation variable is expressed in the index of positive and negative correlation coefficients. If it shows a negative correlation, it means it is inversely proportional, while a positive correlation shows a direct proportionality [24]. The correlation degrees used are as follows:
Table 4. Guidelines for degree of correlation [24].

| Pearson Correlation | Correlation Degrees         |
|---------------------|-----------------------------|
| 0.00 – 0.20         | There is no correlation     |
| 0.21 – 0.40         | Weak correlation             |
| 0.41 – 0.60         | Medium correlation           |
| 0.61 – 0.80         | High correlation             |
| 0.81 – 0.100        | Very high correlation        |

4. Results and Discussion

4.1 Results
The research results regarding the scientific attitudes of students in the experimental and control class are described in Table 5.

Table 5. Data results of students’ scientific attitudes.

| No | Indicator         | Percentage (%) |
|----|-------------------|----------------|
|    | Experiment Class  | Control Class  |
| 1  | Attitude of Curiosity | 94.8          | 95.7          |
| 2  | Active            | 97.4          | 97.4          |
| 3  | Careful           | 93.1          | 94.0          |
| 4  | Honest            | 93.1          | 94.0          |
| 5  | Discipline        | 95.7          | 95.7          |
| 6  | Cooperation       | 94.8          | 94.0          |
|    | Average           | 94.8          | 95.1          |
|    | Category          | Very high     | Very high     |

Data regarding student learning outcomes are presented in Table 6 below.

Table 6. Data results of students’ pretest and posttest.

| Class  | Data     | N  | Minimum Value | Maximum Value | Average | Deviation Standard |
|--------|----------|----|---------------|---------------|---------|--------------------|
|        | Pretest  | 29 | 10            | 43            | 25.2    | 9.60               |
|        | Posttest | 29 | 50            | 93            | 78.6    | 11.24              |
| Control| Pretest  | 29 | 10            | 43            | 25.2    | 9.64               |
|        | Posttest | 29 | 47            | 93            | 77.9    | 11.38              |

The results of the correlation and regression test regarding the scientific attitudes correlation are presented in Table 7.

Table 7. Results of correlation and regression test of scientific attitudes on learning outcomes.

| Correlation Test * | Regression Test          |
|--------------------|--------------------------|
| $r_{count}$        | $r_{table}$              |
| Sig. (2 tail)      | Significance             |
| R                  | R Square                 |
| Adjusted R Square  | Significance             |
|                   | Correlation impact       |
| 0.346              | 0.254                    | 0.00                  |
| Correlated         | 0.346                    | 0.120                 |
| 0.104              |                          |

*) $r_{table}$ = Test if $r_{count} > r_{table}$ (correlated) / sig value < 0.05 (correlated)
4.2 Discussion

Based on Table 5, it is known that the two classes have almost the same average score (experimental class: 94.8%, control class: 95.1%). Both categories are very high. Thus, these findings indicate that practicum activities using a smartphone microscope based on the STEM approach can improve the students’ scientific attitude as well as the control class using a light microscope. The high acquisition of scientific attitudes is based on practicum activities carried out. Through practicum activities, students are very interested in observing objects related to their environment. According to research by Pertiwi et al. [7], it is stated that learning through practicum can improve students’ scientific attitudes. It is because the learning model directly involves students to learn interactively and not only learn the concept. Practicum activities also invite and motivate the students to explore objects around which is rarely done by them. Another finding by Damayanti et al. [25] and Rohaeti et al. [26] explained that to attract participants’ curiosity, the teacher can use the contextual phenomena of local wisdom so that learning becomes good meaningful and can bring up the scientific attitude of students.

Meanwhile, the learning outcome data in Table 6 shows that the students' mastery of concepts after both classes' pretest was still low. This is very reasonable considering that students have not studied the material. After being given different treatments, the students then given a final test (post-test) in each class, it showed that the students’ mastery of the material in both classes increased. It is in line with Khoiri’s [27] statement stating that this can be seen from the STEM learning steps that hone students' abilities in designing and creating something to be used in PBM. Besides, the improvement of scientific attitudes in the experimental class was due to the combination of practicum and STEM approach. This finding agrees with a study by Pertiwi [28] regarding the application of STEM in practicum, that STEM can develop students’ scientific attitudes when related to the environment or practicum, so that learning presents the real world experienced by students.

The relationship between scientific attitudes towards learning outcomes is obtained (Table 7) that $r_{\text{count}}$ (0.346) > $r_{\text{table}}$ or a significant value (0.00) < 0.05. It means that scientific attitude has a positive correlation (with weak correlation degree) towards students' learning outcomes. Meanwhile, based on the regression test results, the coefficient of determination ($R^2$) was 0.120, indicating that the scientific attitudes explain the variance of learning outcomes by 12.0%. This means that the more positive students' scientific attitude, the higher the learning outcomes of students, and vice versa. This can happen that a high scientific attitude will support students in obtaining good learning outcomes because a scientific attitude trains students to be active, disciplined, honest, responsible, and rigorous in learning. This finding agrees with the percentage acquisition rate of scientific attitudes in both classes which is very high (Table 6). According to the research results of Yunita et al. [29], there is a positive and significant correlation between students' scientific attitudes and learning outcomes. So, the effort that can be made to improve learning outcomes in students is to grow and instill a positive scientific attitude towards subjects because by having a positive scientific attitude in learning, the students will be more engaged in learning. Another study by Razak and Kamaruddin [30], found that there is an influence between scientific attitudes and learning outcomes. This shows a strong impact by influencing each other, where students' scientific attitudes affect learning outcomes or vice versa. This can occur because students' scientific attitude is an attitude that is not forced by someone to act in learning something but emerges from the students themselves, thus encouraging students to achieve optimal learning goals.

5. Conclusion

Students' scientific attitude on the topic of Animalia using a smartphone microscope based on the STEM approach as a practicum tool in the experimental class and applying the light microscope in the control class were both categorized as very high. Besides, there is also a positive correlation between scientific attitudes and student learning outcomes.
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