Development of student worksheets based on STEM approach to improve students' critical thinking skills

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Abstract. The development of Worksheets based on the STEM approach pays attention to the elements of writing, the hierarchy of materials, and the selection of questions as an efficient and effective stimulus. This research aims to produce Worksheets based on the STEM approach that meets the feasibility of improving students' critical thinking skills. The development model in this research refers to the 4D (four-D) research and development model by taking sample data from high school science students in the former Besuki Residency, namely Jember, Situbondo, Banyuwangi, and Bondowoso Regencies. The research instrument uses tests, observations, and documentation. The research results show that Worksheets based on the STEM approach meet the valid, practical, and effective criteria for improving students' critical thinking skills. This research implies that the availability of Worksheets is expected for students to research teaching materials independently. In Worksheet, students will get materials, summaries, and assignments related to the material.

1. Introduction

Science is the science of nature that studies objects, phenomena, and processes that occur in nature, and science is concerned with systematically finding out about nature. In essence, science is built based on scientific methods, attitudes, and products. The importance of researching science is to discuss, examine, and prove the existence of facts and natural phenomena related to science learning. Science learning is related to how to find out about nature systematically. Science learning is memorizing and understanding concepts and facts that occur in nature and a process of discovery. The research results indicate that learning science that allows students to find an idea independently will provide direct experience to understand the natural surroundings scientifically [1].

Science learning based on the STEM Approach consists of four elements: integrated science, technology, engineering, and Mathematics [2]. The STEM approach is a multidisciplinary approach to learning, where accurate scientific concepts are combined with the natural world through the practical application of students' science, technology, engineering, and mathematics. Through the STEM approach, students are not just memorizing concepts but also how they understand science concepts and their relation to everyday life. Learning physics in class will be more meaningful for students [4]. Students who learn through the STEM approach can also be independent and develop themselves to gain confidence and work within a specific time [3].

The results of the Research Group research based on road maps in 2018, 2019, 2020 provide an overview of follow-up that is relevant to needs, including: (1) there are no standardized Worksheets so that they are not optimal in supporting the achievement of learning objectives; (2) has not adopted a
STEM approach that is following the development of the globalization era in the learning process; (3) the need for Worksheets that can improve critical thinking skills through the STEM approach. The STEM approach develops when it is connected to the environment and everyday life to present real-world learning experienced by students. The availability of Worksheets based on the STEM approach will assist teachers in preparing lesson plans, as a guide for teachers and students to add information about the concepts learned through systematic learning activities, help students to add information about the concepts learned through organized learning activities, and train students to find and develop critical thinking skills [4].

Seeing the current conditions, the progress of science, science, and technology continues to develop, it is critical to think that the Worksheet, which is also included as teaching materials that are very much needed, must be designed in such a way as to adapt to the times, to prevent learning problems that arise due to insufficient knowledge and skills. Student skills due to the undeveloped teaching materials used [5]. The existence of the Worksheet has a considerable influence on the teaching and learning process. Compiling Worksheet must meet specific requirements to become a good quality Worksheet so that it can support increasing student activity in the learning process and optimize learning outcomes [6].

Students need to have critical thinking skills to face various problems, solve problems, and make the right decisions critical thinking skills will train students to think logically and not accept things easily [7]. Critical thinking skills have several indicators, including (1) giving simple explanations; (2) building basic skills; (3) concluding; (4) providing a further explanation; and (5) setting strategy and tactics. Developing students’ critical thinking skills in learning is an effort to improve student learning outcomes critical thinking skills are thoughtful and reasoned ways of thinking focused on making decisions to solve problems. Critical thinking allows students to analyze their minds in making choices and drawing conclusions correctly.

Therefore, the Research Group needs to produce appropriate STEM Approach-based Worksheets based on valid, practical, and effective criteria to improve students’ critical thinking skills.

2. Method

The type of research used is Research and Development research. This type of research is used to develop or validate products used in education and learning [8]. The sampling technique used is purposive sampling based on specific considerations with criteria so that the data obtained will be more representative. The sample in this research were high school students at the Ex-Residency of Besuki. The research implementation time is in the Odd Semester of 2021/2022. The development model in this research refers to the 4D (four-D) research and development model [9]. The 4D research and development model consists of 4 main stages: define, design, develop, and disseminate [10].

Data collection techniques include: (1) tests conducted to determine student mastery of learning materials and critical thinking skills; (2) interviews were conducted with teachers and students conducted before and after learning; (3) a questionnaire in the form of a validation sheet used to obtain assessment data on the quality of Worksheet; (4) photo documentation of learning activities and other documents that support the implementation of this research.

Data analysis techniques Validation through quantitative data is obtained from the results of the checklist (√) of each validation sheet as follows [11].

\[ P = \frac{\sum X}{\sum X_i} \times 100\% \]

Explanation : 
- \( P \) = Percentage 
- \( \sum X \) = Respondent's score in one item 
- \( \sum X_i \) = The ideal number of scores in one item 
- 100% = Constanta

Further analysis for the criteria for the level of validity is as follows [12].
Table 1. Level of product validity and revision

| Percentage     | Explanation | Score |
|----------------|-------------|-------|
| 81% - 100%     | Valid       | 4     |
| 61% - 80%      | Quite valid | 3     |
| 41% - 60%      | Less Valid  | 2     |
| <40%           | Invalid     | 1     |

Practical data analysis technique through the analysis of the implementation of learning is done by describing the observation of the implementation of learning as follows [4].

\[
\text{Percentage} = \frac{\text{Score obtained}}{\text{Total Score}} \times 100\%
\]

Table 2. Criteria for learning implementation observation scores

| Criteria       | Interval          |
|----------------|-------------------|
| Very good      | 81.25 < 100       |
| Good           | 71.5 < 81.25      |
| Medium         | 62.5 < 71.5       |
| Low            | 43.75 < 62.5      |
| Very Lows      | 0 < 43.75         |

Effectiveness data analysis techniques are through indicators of students' critical thinking skills, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation. The N-gain test to determine the improvement of students' critical thinking skills is as follows [13].

\[
N - \text{Gain} = \frac{(Post \text{ test Score}) - (Pre \text{ test Score})}{(Maximum \text{ Score}) - (Pre \text{ test Score})}
\]

Table 3. N – Gain criteria

| N – Gain Value | Interpretation |
|----------------|----------------|
| g ≥ 0.70       | High           |
| 0.30 ≤ g ≤ 0.70| Medium         |
| g ≤ 0.30       | Low            |

3. Result and Discussion

3.1. Validity

Data on the results of the validity of the developed product were obtained using a validity sheet which was assessed by three validators, including material substance, learning design, and use of Worksheets. Validity was also carried out on the instruments used to support this research, including the questions of pre-test and post-test.

Table 4. Validation assessment results

| No | Assessment Aspect       | Interval Score | Percentage (%) | Criteria |
|----|-------------------------|----------------|----------------|----------|
|    |                         | Validator 1    | Validator 2    | Validator 3 |          |
| 1  | Material Substance      | 0.94           | 0.98           | 0.78      | 90%      | Valid    |
| 2  | Learning Design         | 0.95           | 0.90           | 0.80      | 87%      | Valid    |
| 3  | Worksheet Utilization   | 1.00           | 1.00           | 0.97      | 99%      | Valid    |
|    | Average Score           | 0.96           | 0.96           | 0.85      | 92%      | Valid    |

Based on Table 4 above shows that most of them are in the valid criteria. This is because the validity indicators used are 90% material substance, 87% learning design, and 99% use of Worksheets that have been developed are feasible to test students. The results showed that the feasibility of the product
produced in the form of Worksheets according to the effects of reviews from experts was very good with several aspects, namely the content of the material, elements of the use of learning media, and aspects of Worksheet design. In addition, the research results stated that the feasibility of the developed Worksheet product was good with general characteristics, aspects of material substance, and aspects of learning design. The validity of the media obtained from the material aspect and the aspect of media utilization have met the valid criteria and are suitable for use in learning activities [12].

3.2. Practicality
Worksheets based on the valid STEM Approach are continued at the trial stage. The data on the results of the learning development test was obtained by conducting a development test in high school. The development test was carried out in 3 meetings. The development test data obtained in this development research is data on the implementation of learning using Worksheet based on the STEM Approach to improve students' critical thinking skills. The practicality of learning using Worksheets based on the STEM approach was obtained through observers on the implementation of learning during the learning process.

Table 5. The results of the observation of the implementation of learning

| Activity | Meeting | Average Score | Criteria |
|----------|---------|---------------|----------|
|          | 1       | 2             | 3        |
| Preliminary | 0.87   | 0.94          | 0.87     | 0.89 | Very good |
| Core      | 0.96   | 0.96          | 0.93     | 0.95 | Very good |
| Closing   | 0.95   | 0.90          | 0.90     | 0.92 | Very good |
| Average   | 0.93   | 0.93          | 0.90     | 0.92 | Very good |

Table 5 above shows that the implementation of learning using Worksheet in three meetings based on aspects of the preliminary, core, and closing activities got an average score of 0.92. So that on average each activity has been carried out very well. This follows the research results that the implementation of learning with preliminary, core, and closing activities can be carried out well. The implementation of learning is applied because STEM-based Worksheets are easy for students to use and easy to use by teachers to implement learning and minimize time [14]. Seeing the current conditions, the progress of science, science, and technology continues to develop, it is necessary to think that the Worksheet, which is also included in the teaching materials that are very much needed, must be designed in such a way as to be adapted to the times, to prevent learning problems that arise due to insufficient knowledge and skills. Student skills due to the undeveloped teaching materials used [6].

3.3. Effectiveness
The effectiveness in this trial is the effectiveness of the product developed in the form of Worksheets based on the STEM approach by looking at student test results to see the level of development of students' critical thinking skills. The data used to determine the effectiveness after using Worksheet based on the STEM Approach is necessary to do a test. The tests carried out were in the form of a pre-test which was carried out before being given the Worksheet based on the STEM approach that was developed, and the post-test was carried out after.

Table 6. Results of critical thinking skills

| No | Indicators of Students' Critical Thinking Skills | Pre-test | Post-test | N-gain | Criteria |
|----|-----------------------------------------------|---------|-----------|--------|----------|
| 1  | Interpretation                                | 54%     | 71%       | 0,37   | Medium   |
| 2  | analysis                                      | 52%     | 75%       | 0,48   | Medium   |
| 3  | Evaluation                                    | 62%     | 86%       | 0,63   | Medium   |
| 4  | Inference                                     | 35%     | 61%       | 0,40   | Medium   |
The critical thinking skills test is used as many as six questions, and each question contains one indicator of critical thinking skills. Based on Table 6 above shows that the explanation indicator is the largest; this is because students practice their critical thinking skills by explaining or making arguments that are supported with the right reasons. In the pre-test and post-test questions, students were asked to explain the material. After observing the picture, students can explain or make an argument correctly. In addition, this explanation indicator obtained the highest N-Gain score. The average N-Gain for students' critical thinking skills on the explanation indicator is 0.87 with high criteria. This is following the research that the explanatory indicator with a score range of 81-100 has very high criteria. In his research, he carried out activities to train students in stating results and providing appropriate arguments [15]. These activities are always trained to students so that students get used to giving opinions appropriately, and these activities can prepare students to develop critical thinking skills [9].

The lowest increase is in the self-regulation indicator, and this is because the questions given to this self-regulation indicator are students control themselves to solve a problem regarding important things from the occurrence [16]. From the students' answers, the average N-Gain score for students' critical thinking skills activities on this self-regulation indicator is 0.15. This is in accordance with the research that self-regulation indicators carry out self-control activities in associating problems with each other's concepts. However, the low number of students in this indicator is caused by several factors, one of which is not optimal learning to utilize self-regulation critical thinking skills [11]. In addition, this is following the results of the research showing that the problem that students must solve is in their ability to control themselves in dealing with a problem by applying their ability to analyze and evaluate what is obtained by themselves so that their ability to think critically increases [17]. Even though students know the concept, they may not know how to control themselves to apply it, so they have difficulty relating concepts to one another.

4. Conclusion

Based on the results of data analysis and discussion, it can be concluded that the Worksheets are based on the STEM approach that meets the valid, practical, and effective criteria for improving students' critical thinking skills. This research implies that the availability of Worksheets is expected for students to research teaching materials independently. In Worksheet, students will get materials, summaries, and assignments related to the material.

Acknowledgments

The successful implementation of this research cannot be separated from the help of various parties, for that the research team of Inovasi Media Pembelajaran Sains Non-Elektronik Research Group would like to thank LP2M Jember University through the Research Group Grants and Research Partner Schools with Assignment Agreement Number 2702/UN25.3.1/ LT/2021.

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