Development of STEM Model Student Worksheets with PhET Simulation on Hooke’s Law Material to Improve the Ability Students' Critical Thinking

F R Agustina and Dwikoranto*
Physics Education, Faculty of Science and Mathematics, Universitas Negeri Surabaya, Indonesia.

*Email: dwikoranto@unesa.ac.id

Abstract. This research aims to describe the feasibility of STEM model student worksheets in guided inquiry learning with PhET Simulation media on Hooke’s Law material in terms of validity, effectiveness and practicality, due to the lack of critical thinking skills of students. This development research uses a four-D model with the following steps: design, define, develop and disseminate with high school students as research targets. Data were analyzed descriptively quantitatively. The results showed that: (1) The level of validity of student worksheets get a score of 86.36% with a very valid category; (2) Practicality level of student worksheets get through observation sheets and questionnaire responses from students get a practicality score of 88% with a very practical category; and (3) The level of effectiveness of the worksheets obtained from the N-gain calculation get a score of 0.56 in the medium category. Based on these things, it can be concluded that the developed student worksheets are feasible to be used to improve the ability students' critical thinking.

1. Introduction

The current era is the industrial revolution era 4.0 or can be said that the current era has entered the 21st century. The characteristics of industrial revolution era are digitization, optimization production, customization production, automation and adaptation, interaction of human with machines, value-added services and businesses, automatic data exchange and communication, as well as using information technology [1].

In line of the times, the curricula of educational is also developing. Currently using the curriculum of 2013 which emphasizes the learning process with a scientific approach means providing understanding to students in recognizing, understanding various materials using a scientific approach.

The STEM model is one of the learning that is in accordance with the curriculum of 2013 which emphasizes the learning process so that students can understand any various materials using a scientific approach. This model of STEM is an integration of the four disciplines of science, technology, engineering and mathematics learning which are suggested to be able to help the successful development of 21st century skills [2]. One of the efforts that can be taken to increase the quality of education is the development of student worksheets. Student worksheets are generally a learning tool as a complement or a means of supporting the implementation of the Lesson Plan [3]. Student worksheets are a tool used to assist the learning process so that interactions between students and teachers are formed and can increase learning activities and achievements [4].

The development of STEM-based student worksheets can solve problems for students and teachers. The developed student worksheets contain four disciplines, they are science, technology, engineering and mathematics. Student worksheets can be used to increase science process skills and higher order thinking skills. The use of STEM in learning activities that are applied in the form of student worksheets can have a good impact, including being able to improve conceptual understanding and students' critical
thinking skills [5]. STEM can train critical thinking skills, as evidenced by an increase in thinking skills on each critical thinking indicator [6]. Critical thinking skills referred to in this study are students' analytical and evaluative abilities to process information and experiences obtained in the learning process, with indicators of skills to interpretation, analyze, evaluate, explain, and draw conclusions. Critical thinking skills will make students able to make decisions or actions on the problems they face. This critical thinking skill will equip students in dealing with every problem in everyday life [7].

In the implementation in the classroom, it is combined with guided inquiry which places students in solving a problem by formulating hypotheses, collecting data, testing hypotheses to drawing conclusions by students [8]. There was an enhancement in the ability critical thinking after the application of guided inquiry learning in the class [9]. Guided inquiry is able to motivate students to become individuals with a high level of intelligence with their critical and rational thinking and have broad insight [10].

STEM is suitable when combined with guided inquiry so that it can develop critical thinking skills [11]. STEM is a learning and strategy that is seen as an approach that can make changes in 21st century skills [12]. STEM is able to create a modern learning system in the midst of technological developments because it incorporates four disciplines that are really needed, namely science, technology, engineering and mathematics [13]. Continuous application will produce students who have scientific qualifications, are critical and innovative, are skilled in solving mathematical equations, and are able to take advantage of increasingly sophisticated technology along with the times [11].

Aspects of science and technology are two things that are interrelated, these two things are indispensable factors in the development of education in the digital era. Natural sciences including physics are subjects that are closely related to experiments, so with increasingly sophisticated technology we can conduct virtual experiments [13]. One of the virtual physics experimental media that can explain physical phenomena through experiments so that students are able to explore certain concepts and materials through virtual media simulations. Students' critical thinking skills increase after learning that refers to the guided inquiry syntax with PhET simulation experimental media [11].

With the explanation of the educational problems above, it is necessary to conduct research to produce innovative student worksheet material teaching that can be used in learning by linking the disciplines of science, technology, engineering and mathematics, namely the development of STEM-based student worksheets in guided inquiry learning with PhET Simulation on Hooke's law material to improve the ability students' critical thinking.

2. Method

The type of research used Research and Development with a 4-D model (Define, Design, Develop, and Disseminate [1]. The subjects of research are the level of validity, practicality and effectiveness of a STEM model student worksheet in guided inquiry learning with using PhET Simulation on the Hooke’s Law Material to increase the students’ critical thinking. The object used for limited dissemination in this research was class XI students of State Senior High School 1 Sumberrejo Bojonegoro.

The student worksheets integrated STEM were tested using a one group pretest-posttest research design [14]. In this research design, a pretest was given at the beginning of learning, then students were given treatment using a student worksheet developed on the material of Hooke's Law which was then given a posttest at the end of the lesson. The response questionnaire given to students contained questions about student worksheets developed in physics learning.

The Define stage is carried out by determining and defining learning requirements by conducting interviews with physics teachers, analyzing physics learning syllabus, analyzing teaching materials, literature reviews about teaching materials similar to student worksheets. The design stage is carried out by designing student worksheets that will be developed so that they are in accordance with the planned objectives, selecting media, selecting formats, designing student worksheets which include the formulation of indicators and learning objectives, making lesson plans, syllabus, drafts of developed student worksheets, and making learning instruments. The Develop stage is carried out by compiling learning tools, compiling and making student worksheets, observation sheets and questionnaires which will later be validated by expert validators. This stage consists of the validation stage, effectiveness
stage, and practicality stage. The last research stage, namely Disseminate, is the stage of implementing the learning process using student worksheets that have been made.

The instrument used is the instrument of validity, practicality and effectiveness of student worksheets. Student worksheets are declared valid if they reach a minimum of 61 validity criteria. The results are then matched with the validity score criteria which can be observed in Table 1.

| Table 1. Criteria for validity scores [14] |
| No | Score Percentage | Criteria |
|----|-----------------|----------|
| 1  | 0% - 20%        | Not very valid |
| 2  | 21% - 40%       | Not valid |
| 3  | 41% - 60%       | Quite valid |
| 4  | 61% - 80%       | Valid |
| 5  | 81% - 100%      | Very valid |

The practical instrument of a student worksheet is viewed from the observation sheet on the implementation of learning and the results of the questionnaire responses given by students. The assessment data is in the form of a checklist on the response questionnaire that has been distributed. Assessment Student response analysis is based on the Guttman Scale in the form of statements with scores as shown in Table 2.

| Table 2. Guttman Scale Criteria [14] |
| No | Response | Score |
|----|----------|-------|
| 1  | Yes      | 1     |
| 2  | No       | 0     |

Instrument effectiveness of student worksheets in terms of whether or not there is an increase in students' critical thinking skills. The effectiveness of student worksheets can be done through the provision of pretest and posttest questions. Then the score from the question is used to calculate the N-Gain value. Student worksheets are declared effective if they meet a minimum of medium or high criteria. The score criteria can be observed in Table 3.

| Table 3. Interpretation of N-gain Value [15] |
| No | Score N-Gain | Normalized Gain Criteria |
|----|--------------|--------------------------|
| 1  | 0.70 > N-Gain| High                     |
| 2  | 0.30 ≤ N-Gain ≤ 0.70 | Medium                 |
| 3  | N-Gain < 0.30 | Low                     |

The use of N-gain is used to determine the category of process performance improvement and product performance, which is classified as a high improvement category if the N-Gain value is >0.70, medium category if the N-Gain value is 0.30-0.70, or low category if the value is N-Gain <0.30 as suggested by Hake [15].

3. Results and Discussion
3.1 Student worksheet validity
Before the student worksheets are implemented in learning, the student worksheets must go through a validation stage to test the level of validity [6]. Validation was carried out by 2 lecturers of physics education experts. The validation sheet is calculated based on the given score. The validation score by the validator on the development of student worksheets can be seen in Table 4.

| Table 4. Validation score by validator |
| Aspect | Validator 1 | Validator 2 | Total | Percentage | Category |
|--------|-------------|-------------|-------|------------|----------|
| 1      | 5           | 4           | 9     | 90%        | Very valid |
| 2      | 5           | 4           | 9     | 90%        | Very valid |
Based on Table 4, there are 11 aspects of validity studied. The first aspect is that the material refers to the curriculum. In this aspect, a validation score of 90% is obtained and is included in the very valid category. In the second aspect, it covers some of the main concepts on the suitability of content. In this aspect, a validation score of 90% is obtained and is included in the very valid category. The third aspect, namely the activities carried out to support the understanding of the concept, obtained a validation score of 90% and was included in the very valid category. In the next aspect, namely the suitability of the display that contains aspects of the student activity sheet format, it makes it easier for students to learn to get a validation score of 80% and fall into the valid category. In the fifth aspect, namely the harmony of colors, text, images and tables, the validation score is 80% and is included in the valid category. Furthermore, the aspect containing STEM elements obtained a validation score of 90% and was included in the very valid category according to research [3-6]. Furthermore, the suitability of the presentation consists of several aspects in the seventh aspect, namely the aspect of clearly stating the learning objectives and obtaining a validation score of 90% and is included in the very valid category. In the eighth aspect, namely the aspect of including instructions or procedures for students clearly obtaining a validation score of 80% and included in the valid category. In the ninth aspect of the suitability of the presentation, namely critical thinking skills, it gets a validation score of 80% and is included in the valid category. In the last assessment aspect, namely linguistic suitability, consisting of the tenth aspect, namely conformity with standard and correct Indonesian language rules, it obtained a validation score of 90% and was included in the very valid category. Then in the eleventh aspect, namely the use of language effectively and efficiently, it obtained a validation score of 90% and was included in the very valid category.

Based on Table 4 which is described, it can be said that all aspects of the validation instrument are categorized as very valid, meaning that the developed student worksheets are suitable for use in learning [2-3].

3.2 Student Worksheets Practicality

| Aspect | Score | Category |
|--------|-------|----------|
| 1      | 100%  | Very practical |
| 2      | 100%  | Very practical |
| 3      | 80%   | Practical |
| 4      | 80%   | Practical |
| 5      | 80%   | Practical |
| Average| 88%   | Very practical |

The feasibility of the practical aspect was assessed from the results of the student response questionnaires given after the learning activities using the developed student worksheets [16]. The response questionnaire consists of 5 questions that will be answered by students with "Yes" and "No" answers. Assessment of the response questionnaire using the Guttman scale obtained a percentage value
of 88% with a very practical category. This shows that the developed student worksheets are declared feasible from the practical aspect.

3.3 Student Worksheet Effectiveness
The effectiveness of student worksheets can be seen and measured from the learning outcomes before doing the learning (pretest) and the learning outcomes after doing the learning (posttest). The learning outcomes can be used to determine the improvement of students' critical thinking skills, if there is an increase, the student worksheets are proven to be effective in learning.

| Table 6. Calculation results of N-Gain |
|--------------------------------------|
| Abs | Test Student Score | | Category |
| | Pre-test | Post-test | N-gain | |
| 1 | 30 | 70 | 0.57 | Medium |
| 2 | 30 | 80 | 0.71 | High |
| 3 | 70 | 90 | 0.67 | Medium |
| 4 | 30 | 70 | 0.57 | Medium |
| 5 | 40 | 70 | 0.50 | Medium |
| 6 | 50 | 70 | 0.40 | Medium |
| 7 | 60 | 90 | 0.75 | High |
| 8 | 30 | 70 | 0.57 | Medium |
| 9 | 50 | 70 | 0.40 | Medium |
| 10 | 60 | 80 | 0.50 | Medium |
| Average | 45 | 76 | 0.56 | Medium |

From the N-gain calculation above, an average score of 0.56 is obtained in the medium category. Based on the use of STEM-based student worksheets using PhET media on Hooke’s Law material which is applied to guided inquiry learning is able to optimize students' critical thinking skills [2]. Table 6 shows that STEM-based student worksheets in guided inquiry learning with help of PhET Simulation media on Hooke’s Law material obtained effective results in improving critical thinking skills of the State Senior High School 1 Sumberrejo Bojonegoro students.

4. Conclusion
Based on research that has been carried out the State Senior High School 1 Sumberrejo Bojonegoro by conducting learning using STEM-based student worksheets in guided inquiry learning with the help of PhET Simulation media on Hooke’s Law materials to improve students’ critical thinking skills, the results obtained in the form of the level of validity, practicality and effectiveness of the developed student worksheets. At the student worksheet validation stage, a score of 86.36% was obtained and was included in the very valid category. In the aspect of practicality, a score of 88% is obtained and is included in the very practical category. At the implementation stage using the one group pretest posttest design, the N-gain was 0.56 and was included in the medium category. Thus, it can be concluded that the developed student worksheets meet the criteria of being valid, practical and effective in improving the ability critical thinking.

References
[1] Ramli R, Yohandri Y, Sari, Y S, and Selisne M 2020 J. Eksakta Pendidik. 4 10
[2] Aldila C, Abdurrahman A, and Sesunan F 2017 J. Pembelajaran Fis. 5 85
[3] Syamsurizal S, Epinur E, and Marzelina D 2014 J. Indones. Soc. Integr. Chem. 6 35
[4] Umbaryati U 2016 PRISMA Pros. Semin. Nas. Mat. 217
[5] Pangesti K I D, Yulianti, and Sugianto 2017 J. Literasi Pendidik. Fis. 2 44
[6] Pertiwi R S, Abdurrahman A, and Rosidin U 2017 J. Pembelajaran Fis. 5 11
[7] Facione P A 2013 Critical Thinking: What it is and Why it Counts Retrieved from: https://www.nyack.edu/files/CT_What_Why_2013.pdf
[8] Nur’Azizah H, Jayadinata A K, and Gusrayani D 2016 J. Pena Ilm. 1 51
[9] Puspita A T and Jatmiko B 2013 Inov. Pendidik. Fis. 2 121
[10] Nurmayani L and Nurmayani L 2018 J. Pendidik. Fis. Teknol. 4 98
[11] Fitriyah L and Madlazim 2021 J. Inov. Pendidik. Fis. 10 99
[12] Khairiyah Nida’ul, 2019 Pendekatan Science, Technology, Engineering and Mathematics (STEM) (Medan: Guepedia)
[13] Sukmana R W 2018 Pendas: J. Ilm. Pendidik. Dasar 2 189
[14] Riduwan 2015 Skala Pengukuran Variabel-Variabel Penelitian (Bandung: Alfabeta)
[15] Hake R R 1998 J. Phys Am. Assoc. Phys. Teach. 66 64
[16] Simatupang H, Sianturi A, and Alwardah N 2019 J. Pelita Pendidik. 7 170