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Problem-Based Learning with Interactive Multimedia to Improve Students' Understanding of Thermodynamic Concepts

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Abstract: This paper develops an interactive multimedia on the thermodynamic concept with the main purpose to examine its implication on physics teaching with problem-based learning model. This research was conducted in three stages, namely preliminary study, development stage, and field testing stage. The validator has validated the interactive multimedia. The testing phase used one group pretest&post-test design. The instrument used to measure mastery of concepts is a question about each concept of thermodynamics. The results showed that the average students' concepts mastery in the sub-material of the second law of thermodynamics was higher than that of other sub-materials. In general, an increase in students' mastery of thermodynamics concepts was in the medium category. This shows that interactive multimedia in problem-based learning succeeded in increasing students' mastery of thermodynamic concepts.

Keyword: Problem-based learning, Interactive multimedia; Thermodynamic concepts

1. Introduction

Physics has an essential role in the development of technology. Educational providers need to prepare students to enter the era of globalisation. In global competition, students need to be equipped with various abilities and skills, one of which can utilise information and communication technology (ICT) in learning. ICT facilitates new methods for finding and obtaining various information available through interactive multimedia. According to Gunawan [1] interactive multimedia is a combination of various media packaged in the form of learning CDs that contain elements of text, sound, images, video, and animation into a single presentation makes it easy for teachers to design relevant media and the learning process becomes more attractive for students that improve the quality of student learning outcomes. Rajendra and Sudana [2] stated that the use of interactive multimedia and the selection of the appropriate learning model became an important part, especially to develop reasoning, activeness, and student learning motivation. The learning model was used to help the interaction between student and teachers thus helping them in mastering concepts in physics. One of effective learning model increases the mastery of students' physics concepts through the problem-based learning model. Maryati [3] States that the problem-based learning model significantly increases the mastery of concepts in physics learning. Nurqomariah *et al.* [4] stated that the problem-based learning model with the experimental method showed a significant increase in mastery of the concept of physics.

One of the basic concepts in physics is thermodynamics. Thermodynamics has a dynamic character, many abstract concepts, and concepts based on principles. Abstract concepts make it difficult for

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students to understand the concepts taught by the teacher. According to Gunawan *et al*. [5], there are some common difficulties encountered in thermodynamic learning, such as interpreting graphs, mastering their physical equations and interpretations, understanding thermodynamic concepts, and their application in daily life day. Problems found to affect students' ability and skill of mastering the concept of thermodynamics.

The thermodynamic concept can be realized through the use of computer technology in the form of interactive multimedia software. Dega *et al*. [6] stated that interactive multimedia can simplify abstract thermodynamic concepts such as enthalpy and entropy. According to Chen *et al*. [7], abstract concepts can be visualised concretely so that easier to be understood by students. In line with Tambunan and Napitupulu [8] the use of interactive multimedia can simulate complex processes and abstract concepts Several related studies show that the use of interactive multimedia in learning has been able to help and facilitate the increase of concepts mastery on a thermodynamic material. Liu [9] found that the use of computers in thermodynamic learning cases effectively improves problem-solving abilities in the material of thermodynamic law. Husein *et al*. [10] stated that interactive multimedia could improve the mastery of concepts on temperature and heat material. Based on the background of the problems described above, interactive multimedia has been developed and implemented in problem-based learning to improve the mastery of the thermodynamic concept. Through the use of interactive multimedia, students are expected to be able to improve concept mastery of thermodynamics.

The rest of this paper is organized as follow: Section 2 describes the proposed research method. Section 3 presents the obtained results and following by discussion. Finally Section 4 concludes this work.

2. Proposed Method

This research is research and development. In the testing phase, it used a quasi-experimental method with one group pretest&post-test design. The subjects of this research are students of 3 Senior High School in Mataram, as many as 40 people in the 2017/2018 academic year. The test was developed to measure the increase in multiple-choice concept mastery consisting of 25 items in the Thermodynamics concept. The test includes concept mastery indicators according to Krathwohl [11] which are aspects of remembering (C1), understanding (C2), applying (C3), analysing (C4), evaluating (C5) and creating (C6).

The increase in the application of interactive multimedia physics in problem-based learning in mastering the concept of thermodynamics is determined based on the average normalized gain score, (N-gain). The equation calculates N-gain:

$<g> =$

with $<g>$ being the normalized gain, S_{maks} is the maximum (ideal) score from the initial test and the final test, S_{post} is the final test score, while the S_{pre} is the initial test score. N-gain can be classified as follows: $g > 70$ (height), $30 \leq g \leq 70$ (medium) and $g < 30$ (low).

3. Result and Discussion

In this study, interactive multimedia has been developed in problem-based learning to improve the students' concepts mastery of thermodynamics. Interactive multimedia includes several thermodynamic concepts including the zeroth law of thermodynamics, the first law of thermodynamics, second law of thermodynamics, and entropy. Display of products that have been developed are shown in Figure 1.

Figure 1. Example of Interactive Multimedia Interface Thermodynamics: (a) front page; (b) videos; (c) animation; (d) virtual experiments.

Interactive multimedia components that have been developed using five main components, namely the Theory contains essential concepts of thermodynamics, which are complementary to the textbooks owned by students. In this section, there are animations related to the concepts learned. The animation is used to help students understand a thermodynamic cycle process. Animation has helped students in developing thinking skills, and each animation comes with a brief explanation. Videos in MMI are used to provide a more realistic explanation. Simulations are used to carry out the main activities of students in developing investigative abilities. Virtual experiments were added to a question sheet that allows students to experiment virtually, formulate hypotheses, collect, analyze data, and draw conclusions. Practice questions are used at the end of learning after learning the concept of thermodynamics to test students' understanding. This exercise was designed by giving students back to check the authenticity of their answers.

Interactive multimedia that has been developed includes several sub-concepts. Each sub concept has interactive animations and simulations to support the learning process. In the concept of zeroth law of thermodynamics, there is an interactive simulation that helps students to observe the process related to the concept. In addition, students are given the freedom to change variables and see direct effects on other variables. Interactive multimedia that has been developed can help students discover their important concepts and principles in physics.

Multimedia was developed to be a physics learning tool for teachers and students. Multimedia was created so that it can be used independently by students with the help of student worksheets. In general, this multimedia is also used as a media presentation by teachers in the classroom. In interactive multimedia learning is applied in the problem based learning (PBL) model. Learning the law of thermodynamics lasts for 90 minutes in directing students to find concepts independently.

Concept mastery data was collected using concept mastery instruments. Instruments in the form of multiple choice questions were 25 questions which were spread over six mastery indicators.

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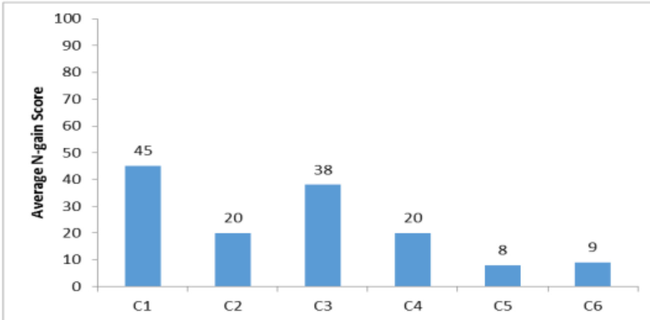

Figure 2. Increased N-gain concepts mastery for every cognitive aspect

Mastery of the concept on the cognitive indicator of remembering has the highest increase. This happens because the level of remembering is easier than the cognitive level of the other. Indicators remember means students get back what has been obtained about concepts in the law of thermodynamics. First law of thermodynamics, the second law of thermodynamics and entropy equation. Kola [12] states that using interactive multimedia is an effective way to improve understanding of physics concepts. Gok [13] also stated that interactive involvement provides more effectiveness towards physics learning.

On indicators understanding, applying, and analysing shows a significant increase in the moderate criteria. This is because students can give reasons for what they answer. Sulistyorini and Ekawati [14] Stated that the difficulties experienced by students in achieving a cognitive level of application level (C3) and analysis (C4) in learning Physics is in understanding the purpose of the problem caused by students not careful in reading the problem, but also understand the concept of physics.

Mastery of concepts on indicators evaluating and creating was the lowest increase. This is because both aspects have a higher level of difficulty compared to other aspects and students are not used to answering questions with evaluating and creating level indicators.

Data of concept mastery in the thermodynamic sub-material in the form of multiple-choice questions as many as 25 items consisting of 4 items sub-material zeroth law thermodynamic, nine items sub-material first law of thermodynamics, eight questions sub-second law of thermodynamic material and four entropy sub-matter questions. Data recapitulation of concept mastery of the thermodynamic material was shown in Figure 3.

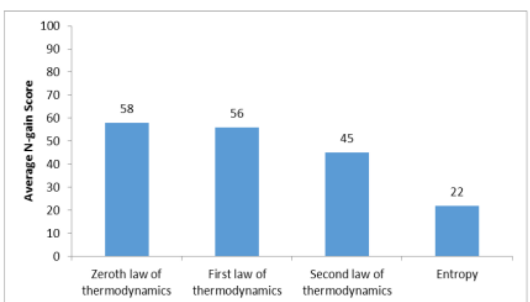

Figure 3. Increased N-gain concepts mastery for every sub-material

The zeroth and first law of thermodynamics has the most significant increase. Because the material of the zeroth and first law of thermodynamics using animation to help students' understanding in the learning process. Suryaningsih [15] stated that learning outcomes using animation media are higher than without using animation. Because animation media is more representative to accommodate subject matter. In the use of animation media, students have the opportunity to 'interact' with the program. Students must click on a specific button, make a selection of features, and pay attention to the impact of the choices made on the animation. This learning process gives students the opportunity to engage more intensely in the learning process, so that understanding becomes better. This is also in line with Edgard Dale's theory that the more student involvement in the learning process is the more complete and meaningful learning process.

The increase in mastery of concepts in the second law of thermodynamic material is equal to 45 in the medium category. This occurs because the material in interactive multimedia contains a video that presents the problem of the cooling and heating process in the heat engine. It is also equipped with an inquiry through simulation activities plus student questionnaires designed to enable students to experiment virtually, in formulating hypotheses, collecting, analysing data, describing each Carnot cycle process and drawing conclusions. Kulkarni and Tambade [16] stated that simulation could encourage students to process in physical research, such as questioning, predicting, hypothesising, observing, and interpreting results. They can also motivate and foster student interest in learning physics.

In the entropy concept, the material has the lowest increase in the low category because of the presentation of material in interactive multimedia using animation with a brief explanation. Also, in the test of entropy concept, there is a calculation with the level of analysis that connects entropy with thermodynamic law II. Christensen *et al*. [17] found that the concept of entropy and thermodynamic law II have broad implications so that they easily confuse understanding them.

Several other studies have shown similar results. Multimedia that has been developed with the right characteristics and principles can improve mastery of concepts and thinking skills [18], [19], [20], [21], [22], and [23].

4. Conclusion

This paper has developed an interactive multimedia on the thermodynamic concept with the main purpose to examine its implication on physics teaching with problem-based learning model. It can be drawn a conclusion that interactive multimedia in problem-based learning has been able to increase students' mastery on the concept of thermodynamics. Mastery of students on the concept of thermodynamics is in the medium category. Students are able to answer questions at a low cognitive level. They still need to learn to answer questions at a higher cognitive level.

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