Improved Understanding of Student Particle Dynamics Concepts Using Basic Physics Modules Based on Concepts

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Abstract. This study stems from the results of observations made by researchers who found that students had difficulty in drawing free diagrams in solving particle dynamics problems that indicated students did not understand the concept of dynamics correctly. Students have difficulty in changing information from one form to another. One of the students' understanding of the concept of Particle Dynamics is one of them caused by the lack of use of appropriate teaching materials in learning Particle Dynamics. This basic concept-based physics module has a concept column that explains the concept of Particle Dynamics precisely. Modules are also equipped with sample questions and discussion related to concepts in the Particle Dynamics material. The purpose of this study was to find out how to increase understanding of students' particle dynamics concepts after using a concept based physics module. The sample of this research was 28 Semester 1 Department of Biology Education IAIN Kerinci students, who were 28 students taking Basic Physics courses. The research method used is a pre experimental method with one group pretest posttest design. Research data were analyzed using \textit{N-Gain}. The results obtained an increase in the medium category with an average value of \textit{N-Gain} \textit{N-Gain} of 0.51. This increase occurs in indicators interpreting, modeling, classifying, summarizing, summarizing, comparing, and explaining

1. Introduction

Physics is a branch of science which contains concepts, principles and theories. The essence of physics is science that studies symptoms through a series of processes known as scientific processes which are built on the basis of scientific attitudes with the results manifested as scientific products composed of three components in the form of concepts, principles, and generally accepted theory \cite{1}. Physics contains concepts that are important in analyzing symptoms or phenomena that occur in everyday human life. Therefore, physics is important to study because it is beneficial for student life. Students can analyze natural phenomena in their life, study, and solve problems with physics.
One of the branches of physics is mechanics. One of the materials in the branch of mechanics is particle dynamics. Particle dynamics discusses the motion of an object by considering the cause of its motion in the form of force. The particle dynamics is a concept that explains the relationship between force and motion \[2\]. Force causes motion in particle dynamics. In solving the problem of particle dynamics, an object-free diagram called free body diagrams is needed which is described by students by changing written question information in the form of words into images \[3\]. The object-free diagram is a branch of mechanics that can be represented in the form of a diagram, a complete graphic with force variables \[1\]. The depiction of this object-free diagram is based on Newton's I, II, and III laws. The accuracy of students in describing the object forces on the object-free diagram depends on the understanding of the students' concepts related to the concepts contained in particle dynamics.

Particle dynamics is one of the materials in physics science that is still considered difficult by students. One of the science materials in the field of physics that is difficult to understand and has many alternative conceptions is Newton's Law or Particle Dynamics \[4\]. Mechanical concepts include Newton's I, II, and III Laws \[5\]. Particle dynamics is a part of the branch of mechanics that needs a good understanding of the concept in solving its problems. Particle dynamics is very important to be mastered and understood to solve physics problems \[6\]. Particle dynamics contains basic concepts that underlie other sciences \[7\].

Understanding of the concept of particle dynamics is needed so that students are able to understand physical phenomena appropriately. The position of understanding the concept is the initial position of students to reach a higher level of thinking. Students will not have a higher level of thinking if they don't understand the concept correctly. Concept is an abstraction that describes the general characteristics of a group of objects, events or other phenomena \[8\]. Concept is the starting point in building the next thought process.

Concept understanding is the level of the thinking process at the second level after the memory level (C1). There are seven indicators of concept comprehension ability which serve as benchmarks that a student understands the concept correctly, while the seven indicators of this ability are \[9\]: a) Interpreting, the ability to interpret includes the ability of students to convert words into other words, pictures into words, words into pictures, and numbers into words or vice versa, b) Exemplifying, this ability to exemplify includes the ability to provide examples related to the concepts that have been learned, c) Classifying, this ability to classify includes the ability to find relevant characteristics or patterns that are in accordance with certain concepts, d) Summarizing, this ability to summarize includes the ability to express or present information received or abstract a concept, e) Inferring, this inference includes the ability to draw relationships from specific characteristics, a series of examples or events, f) Comparing, this ability to compare includes the ability to find differences or similarities from two objects, phenomena, or the like, and g) Explaining, the ability to explain this includes the ability to build and use a cause and effect model of a system. These seven indicators of ability can be an indicator of whether a student has an understanding of the concept or not. This ability can be identified by using conceptual understanding questions using seven indicators of these abilities.

Biology education students have a low understanding of the concept of the concept of particle dynamics. This is evidenced by the results of observations made by researchers in the odd semester 2018 students which were obtained in the form of a) the inability of students to understand the concepts of Newton's Law I, II, and III correctly, this can be seen from when students are given questions the student is unable to classify whether the questions This is included in the concept of Newton's Law I, II, or III, b) students are not able to change the words in particle dynamics problems into the form of object-free diagrams precisely so that there is a fundamental error, and c) students are still unable to explain the concept of particle dynamics precisely. When the questions were replaced with other variations, the students were no longer able to draw the object-free diagram correctly.
Based on these observations, it is found that the ability to interpret, explain, compare, and other abilities in the concept of particle dynamics is still low.

Low conceptual understanding can be overcome with teaching materials that are designed to contain correct concepts and explanation of concepts. Teaching materials are all forms of material used to assist teachers/instructors in carrying out teaching and learning activities in the classroom\cite{10}. Teaching materials are one of the determinants of student learning success. One type of teaching material that can be used by lecturers in helping students understand the material is a lecture module.

Modules are teaching materials that are arranged mathematically by the instructor which includes content, methods, and evaluation which can be used independently to achieve the expected competencies\cite{11}. Furthermore, modules can make it easier for students to understand and remember the material that has been delivered in the learning process\cite{12}. The basic difference between modules and other teaching materials is that in the module students can learn independently by containing teaching concepts that students can learn by themselves (Self instruction), so students will be active in learning\cite{13}. Learning by using modules is also effective in increasing students' understanding of concepts\cite{14}. Even making modules in learning can be adjusted to the character of the students in the class.

Considering the advantages contained in making this module, it makes researchers interested in using a module that contains concepts that can build correct concepts in students in an effort to improve students' understanding of the concept of students who are still low on Particle Dynamics material. The module the researcher means is a concept-based basic physics module. This module is equipped with a column of concepts in each sub-material, examples of conceptual understanding questions, and evaluation questions on concept understanding. A snapshot of the concept-based Basic Physics module used in this study can be seen in Figure 1.

Figure 1. Snippet of Concept-Based Basic Physics Module

This module is also equipped with colorful pictures and images that can represent a concept accurately. This module is used in research with the intention that students have the ability to interpret, exemplify, classify, summarize, conclude, compare, and explain.

Research relevant to this research is research from Roza Damayanti (2018) entitled Development of Basic Physics E-Module I Particle Dynamics Material Based on Kvisoft Flipbook Maker. This research develops modules in exe format and is generated in electronic form on Particle Dynamics...
material. The E-Module developed contains material, animation, video, summary, sample questions, assignments, formative tests, and interactive quizzes in the Basic Physics I lecture \cite{15}. Furthermore, research that is relevant to this research is the research of Prof. Dr. Lufri, M.S., et al (2017) with the title Development of Concept-Based Learning Models, Images and Drill Methods to Improve Students' Ability to Understand Higher-Level Concepts and Thinking in Animal Development Courses. This study uses concept maps in research in an effort to improve conceptual understanding and higher-order thinking. Understanding the concept is seen as important in an effort to build higher order thinking skills for students \cite{16}.

The difference between this study and the relevant previous research is that this study uses a module in the form of printed teaching materials that are selected very suitable to meet student needs. This is due to the fact that students who enter the biology department are students who are not only from the science department but also from social studies. This encourages researchers to present modules that are truly in accordance with the characteristics and abilities of students who are the research subjects of the research. Furthermore, the module is designed based on a concept in the form of a concept column. The concept column is accompanied by a module with the intention of presenting a module that is easily understood by students in the place where the researcher is conducting research. Concept columns accompanied by pictures that represent concepts are considered easier to understand than concept maps which also require a more difficult way of understanding.

This concept-based module is used in research with the aim of knowing the increase in understanding of the concept of particle dynamics of Biology students majoring after using basic physics modules based on concepts on Particle Dynamics material. This research is limited to Particle Dynamics material because this material is often difficult to understand by students. This research facilitates students in independent learning and active learning.

2. Research Method

This study uses a quantitative approach. The quantitative approach is a research that is inductive, objective, and scientific in which the data obtained will be in the form of numbers (score, value) or assessed statements, and analyzed by statistical analysis \cite{17}. This quantitative research usually starts from the theory which is then carried out to prove the truth of the theory through research, and then it is analyzed and conclusions are drawn.

The method used in this research was pre-experimental method with one group pretest posttest design. This study used one class that was selected to be the experimental class by providing an initial test before treatment and a final test after treatment \cite{18}. The initial test is given to find out the understanding of the student's initial concept in the Particle Dynamics material. The final test is given with the aim of obtaining data related to the results of students' understanding of concepts after using a concept-based basic physics module in the basic physics lecture process. The research description can be seen in Table 1.

| Table 1. Research Design |
|-------------------------|
| Pretest | Independent Variable | Posttest |
| Y1      | X                    | Y2       |

Pretest is the initial test before treatment, the independent variable is the use of a concept-based basic physics module, and posttest is the final test after applying the module.

The population in this study is in the form of clusters as many as three clusters, namely local A, B, and C. Sampling from the population using cluster random sampling technique. Samples were taken
randomly by randomizing in groups from the available population. This sampling has the advantage of saving in the cost budget in determining the sample \footnote{19}.

The instrument used to answer this study was a concept comprehension test in the form of an essay, amounting to 12 questions. The ability to understand the concept, which consists of seven indicators of this ability, is summarized in this question. The instrument was analyzed using descriptive statistical analysis. Descriptive statistical analysis aims to describe the characteristics of the distribution of students' conceptual understanding scores by calculating the average pretest and posttest mean with the following equation:

\[
\text{Mean Score} = \frac{\text{Score}}{\text{Maximum Score}} \times 100
\]  

The pretest and posttest mean scores can be interpreted qualitatively by referring to the material understanding level table presented in Table 2 \footnote{18}.

| Understanding Value Range | Understanding Category |
|---------------------------|------------------------|
| 0 – 40                    | Very Low               |
| 41 – 60                   | Low                    |
| 61 - 74                   | Medium                 |
| 75 – 84                   | High                   |
| 85 - 100                  | Very High              |

The average value obtained is then re-analyzed using the <N-Gain> equation as follows:

\[
<N - Gain> = \frac{<Posttest> - <Pretest>}{\text{Smaks.ideal} - <Pretest>}
\]  

\footnote{20} Information :

<\text{N-Gain}> : Average Value of Concept Understanding Improvement

<\text{Posttest}> : The average value of students' understanding of concepts after treatment

<\text{Pretest}> : The average value of students' concept understanding before treatment

Smaks.ideal: Maximum Ideal Score

The N-Gain average value obtained will be interpreted in the form of words based on Table 3 below.

| No.  | Range                  | Category Average Increase |
|------|------------------------|---------------------------|
| 1    | \(<\text{N-Gain}> \geq 0,7\) | High                      |
| 2    | \(0,3 \leq <\text{N-Gain}> < 0,7\) | Medium                   |
| 3    | \(<\text{N-Gain}> < 0,3\)     | Low                       |

3. Results

The research was carried out in Odd Semester 2019 in local A students of the Biology Education Department, totaling 28 students. Before the module is used, the researcher first explains the steps to...
be carried out in the form of giving the initial test first. This notification is made with the intention that students can prepare themselves with the knowledge they may have acquired at the junior high school and high school levels. After being given the initial test, students use the module in the lecture as long as the Particle Dynamics material lasts and ends with a final test in the form of an essay. The pre-test questions and post-test questions are made equivalent to the same level of comprehension skills.

The result of the average score of the initial test given to students was 23.71. These results if adjusted with Table 2 regarding the category level of students’ concept understanding, this score is included in the very low category of conceptual understanding. Furthermore, the average score of the final test given to students was 62.84. This shows that the level of understanding of the Particle Dynamics concept of students after using the concept-based Basic Physics module is in the medium category. After knowing the average final score and initial value understanding the concept, the \( \langle N - \text{Gain} \rangle \) value can be obtained from this study with the following calculations:

\[
\langle N - \text{Gain} \rangle = \frac{62.84 - 23.71}{62.84 - 23.71} = \frac{39.13}{76.29} = 0.51.
\]

The \( \langle N-\text{Gain} \rangle \) value obtained is 0.51 which can be interpreted qualitatively by referring to Table 3 (N-Gain Category Table). This value indicates that the increased understanding of student particle dynamics concepts after using concept-based basic physics modules is in the moderate category.

4. Discussion

Initial test scores that are in the very low category indicate that the student really does not understand the concepts of force, mass, weight, Newton's I, II, and III laws when the student is in the Middle School level. The variation of the majors in local A majoring in Biology Education Semester 1 is also the cause of the very low initial test scores for students' understanding of concepts. There are students who only study physics at the junior high school level and there are also students who study physics at the high school level. This variation is evidenced by the results of the interviews the researchers conducted with the local student coordinator A which produced the following data.

| Majors                | Number of Students |
|-----------------------|--------------------|
| Natural Sciences (IPA)| 18                 |
| Social Sciences (IPS) | 10                 |
| Total                 | 28                 |

The variety of students who are students majoring in Biology Education can be a factor in the very low understanding of students' physics concepts. This is because before going to the understanding stage of thinking, students must first remember the Particle Dynamics material again. However, in reality there are 10 students who no longer remember the material because they have not studied physics for years. This can be an important concern for the campus in selecting students for a particular department in order to form students who are professional in their knowledge.

The final average value after being given treatment is only able to reach the level of understanding the concept in the medium category. This is not in accordance with the expectations of researchers who want students to understand the concept of the high category. After being reviewed, understanding the concept that is only in the moderate category is caused by several factors, including: a) short lecture time with a duration of 2 x 50 minutes for research time, this is carried out in accordance with the Semester Learning Plan that has been made by the Team Basic Physics of IAIN Kerinci, and b) controlling learning using basic physics modules based on less than optimal concepts.
It is better if the researcher uses several lecturers who are teaching other basic physics subjects during the research in order to control the students maximally.

The average N-Gain score which is in the medium category implies that there are still students among the 28 students who still do not understand the concept of particle dynamics. The concept that students find heavy is still in terms of determining the use of the concept in a problem and making object free diagrams in describing the force of an object both in a flat plane and an inclined plane.

5. Conclusion
The conclusion obtained in this study is the concept-based basic physics module used for students majoring in Biology Semester 1 can improve students' understanding of physics concepts in the moderate category. The weakness in this study is the instrument used in the form of an essay which has a question for each child so that the results of this study have not been able to explain clearly on the indicators of which student's ability has not improved significantly. For further research, it is hoped that it can develop basic physics modules in other physics materials and be able to vary the physics module based on this concept with other methods or teaching materials to obtain maximum results.

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