Using Computer Simulation to Teach Mechanics Concept

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Abstract *- Computer technology presents opportunities and innovations in physics learning. Some of the concepts of physics are abstract concepts. Learning abstract concepts requires appropriate media assistance. In this research, we have developed some computer simulation to support learning concept of mechanics. The study aimed to examine the effectiveness of computer simulation toward students' understanding mechanics. The sample used are students from the department of physics education who took mechanics course at University of Mataram. Data were collected using multiple choice and essay test then analysed quantitatively. Data analysis used ANAVA test and N-gain score. The result of the research shows the influence of computer simulation on students' understanding of the concept of mechanics. Improvement occurs in all sub-materials of mechanics. The average for the concept mastery of students in experimental group is higher than that of the control group. Statistically, the difference in the increase in the concept mastery between the two groups did not significantly differ. The improvement in students' concept of learning using computer simulation was higher than the control group who studied conventionally.*

Keywords: *Computer Simulation, Students' Understanding, Mechanics Concept*

INTRODUCTION

The development of information technology has become faster (Khamidov and Kahhorov, 2020). Information and communication technology has reached various aspects of human life, including the realm of education. Finally, some of the human activities are connected with technology. In the 21st century, information technology, thinking ability, and problem-solving are very important for students to increase their knowledge and to contribute to the development of modern society (Kizi and Ugli, 2020). The development of computer technology gives a considerable impact on education, including in physics learning.

Physics as a part of science is closely related to technology. In its application, it automatically generates technology. In addition, theoretical physics is inseparable from technology and industry. The basic principle of Mathematical Modelling is easily applied using technology. A truth must be proven by experimentation in order to get a result that is closest to truth. However, the use of technology in teaching is needed to increase students' thinking levels in the global era. Unfortunately, the lack of resources causes the teaching of physics experiments not to be maximized. Ideally, experiments in physics have a very important role in teaching the students about various skills such as observing, installing tools, measuring, planning research, communicating, and others (Zhou, 2020). Students are easily trained to think creatively in solving problem and find concepts independently. The failure of physics experiments has implications for the low mastery of student physics concepts. Finally, students' problem-solving and creativity skills are not developed.

In conventional learning, methods and learning media that are used are less varied. This causes the student to become passive:

listening, recording the material and equations given, and completing the example of problems given. In addition, some concepts of physics are abstract concepts. Abstract concepts are not easy to visualize and transfer to students. This condition should be considered and given a better alternative solution.

Mechanics is one of the main courses on the structure of the physics curriculum in higher education. The concept of mechanics has always been an introductory subject of physics in high school and university. The concept of mechanics consists of the concepts of 1D and 2D motion, laws of motion, circular motion, energy and displacement, linear momentum and collisions, rotation of rigid bodies, angular momentum, static equilibrium, elasticity, universal gravity, and fluid mechanics. In addition, teaching physics concepts requires adequate experimentation. Some of the concepts of mechanics are abstract, which require media to be visualized, such as quantum mechanics and the concepts of mechanics in modern physics.

One of the alternative solutions offered is using computer simulations. Computer simulations can be used to visualize the concept of physics. Computer simulations used for experiments are called virtual labs (Chen, et al., 2010). In addition, in each of the classroom learning, the computer is enabled to support the implementation of the practice, whether in a real investigation or a virtual experiment. Online learning can be realized informally through the computer. Learning physics is easy through computer simulations. Abstract concepts can be visualized through computer simulation. Therefore, learning physics becomes easier to understand, interesting and fun. Gunawan, et al., (2017) found that physics learning through computer simulation is proven to improve student problem-solving skills. Suranti, et al., (2016) states that the use of virtual media is effective for improving the students' mastery of concepts on every cognitive aspect. The use of computers is the best alternative to increase student physics mastery. Computer technology is not only used to collect, present, and analyse data, but it is even used for experimental modification and presenting the results in virtual form. Gunawan & Liliasari, (2012) found that the use of computer simulations for physics experiments successfully increased the students' critical thinking disposition, such as open-mindedness and truth-seeking when studying the concept of physics.

Through information technology, it is easier for the students to access the information needed to support the learning process (Fabian, et al 2016). Simulation has become an important part of the learning process. Learning through computer simulation allows teachers to convey learning objectives. Sun, et al., (2013) reveals that in the context of education, computer simulations can help instructors to simplify complex operating systems and output systems. In addition, computer simulation allows learners to present simulation results in accordance with their cognitive abilities. Computer simulated users are free to control operational factors and simulation results, repeat the process, make changes, and learn from the simulated environmental feedback. Chen, et al., (2013) reveals that computer simulations have had significant potential as a support tool in effective concept learning based on appropriate technology integration and instructional strategies. McKagan, et al., (2008) asserted that visualization of concepts and abstract processes has helped improve students' mental model and intuition. In addition, it can be used to visualize abstract concepts and microscopic processes that are difficult to observe directly.

The use of computer technology, both in physics learning and experiments, become important in order to improve the quality of learning for prospective teachers. Tondeur, et al (2016) states that teachers' professional development is an important element in the study of education, especially for applying technology to be more effective to improve the quality of learning.

This research has developed several computer simulations to support the learning of mechanics for physics teacher candidate students. This study aims to examine the effectiveness of computer simulations in learning mechanics and its implications on the students' mastery of concepts.

RESEARCH METHODS

This study used pre-test and post-test control group design. This design allows two groups to be selected randomly, then given a pre-test to determine the initial conditions related to the conceptual ability between the experimental group and the control group (Sugiyono, 2013). The sample used are students from the department of physics education who took mechanics course at University of Mataram. There were two groups involved in the study, the experimental and the control groups. The experimental group used direct instruction model by computer simulation while the other class did not. Students' mastery of mechanics concepts in both classes was measured using essay and multiple-choice tests. The test is given before and after treatment. Data were analysed using appropriate statistical tests through SPSS version 20 software. Data analysis included test of homogeneity, normality, and research hypothesis. Improvement in students' understanding of mechanics concept can be determined by N-gain scores.

RESULTS AND DISCUSSION

Before the treatment was carried out, students were given a pre-test to determine initial concept abilities. Furthermore, at the end of the learning process, students are given a post-test to know the students' mastery of concepts. Before the hypothesis test is done, the normality and homogeneity of the data of both groups of samples were tested first. The data normality test results are shown in Table 1 below.

Table 1. Normality Test Result for Concept Mastery in Both Groups

Kolmogorov-Smirnov test (K-S test)	Value of Sig.	Interpretation of conceptual mastery
Pre-test of experimental group	.200(*)	Normally distributed
Post-test of experimental group	.047	Non-normally distributed
N-gain Score of experimental group	.126	Normally distributed
Pre-test of control group	.200(*)	Normally distributed
Post-test of control group	.200(*)	Normally distributed
N-gain score of control group	.076	Normally distributed

Table 1 shows that most test data in both groups are normally distributed. There is one data that is not normally distributed, which is the post-test data of the experimental group. This implies the type of statistical tests that will be performed to test the hypothesis. Homogeneity tests have also been performed as a prerequisite for performing analysis of data variants. Homogeneity test results show that the initial ability of both experimental and control groups is the same. Based on the prerequisite test of data variance analysis, ANOVA test was performed to compare the average score of the concept mastery of each group after treatment. The results of hypothesis testing as a further test on the mastery of the concepts of mechanics are shown in Table 2 below.

Table 2 shows that there is no significant difference in students' mastery of concept between the two groups after treatment.

Table 2. Hypothesis Research Results

Data of T-test / Mann Whitney	Value of Sig.	Interpretation of conceptual mastery between experimental and control groups
Pre-test	.665	Similar
Post-test	.179	Similar
N-gain	.051	Similar

The improvement of conceptualization in both groups also did not differ significantly. This condition occurs because the mechanics concept requires higher-order thinking skill (HOTs) cognitive ability level to understand. Nevertheless, it is noted that the previously-different ability level for both groups improved from 0.665 to 0.179. These results illustrate that, although not significantly different, there is already an indication of stages of conceptual mastery. However, a suitable learning model for subsequent research is essential. The results of this statistical test are exactly the same as Keller, et al's (2006) who discovered that there is no difference in the mastery of concepts between students studying through computer simulations and real laboratory tools. The study discovered that this model had no significant effect on each group of students.

Nevertheless, the average conceptual mastery for the experimental group is higher than that of the control group. The experimental group was given treatment using computer simulation, while for the control group, conventional learning. This result is in accordance with previous research whereby the use of computer simulations for physics experiments has been proven to increase creativity in physics learning (Gunawan et al., 2017), skills in mathematical modelling, logic inference and concept construction (Gunawan, et al., 2013).

In addition, this study performs analysis for each sub-material or concept label. The concept of mechanics tested consists of five concept labels, namely: the concept of kinematics, dynamics, collision, rotation motion, and fluid mechanics. Each concept label was analysed for improvement and achievement according to test results in both groups. These data suggest that the mastery of mechanical concepts in both groups has improved after treatment. The comparison of the conceptual mastery capabilities of the two groups on each concept label is shown in detail in Figure 1. Figure 1 shows that the increase of N-gain for the experimental group is higher than the control group for all sub-concepts. The concept of kinematics is a concept with the highest increase compared to the others. It can be explained as follows: in addition to being the basic material that has been studied at the high school level, explanations of the concept of motion that include position, displacement, velocity, acceleration, free fall motion, circular motion, and bullet motion have been discussed as a basic concept in secondary school. This is the cause of the high increase in the concept of kinematics in both experimental and control groups. Significant differences in both groups show that visualization through virtual simulations and additional explanations help students in the experimental group to recall the material better. Computer simulations can be used to learn the same concepts as the real equipment. Moreover, virtual equipment is even more productive than real equipment. In addition, according to McKagan et al (2008), students' difficulties in quantum mechanics can be solved by PhET simulations. The main features of PhET simulation are visualization, interactivity, context, and effectiveness of computer usage, especially effectiveness in helping students understand abstract concepts and counterintuitive concepts of quantum mechanics. The results of his research show that simulations are used effectively to help students learn and have provided a more comprehensive understanding of the way of thinking about quantum mechanics.

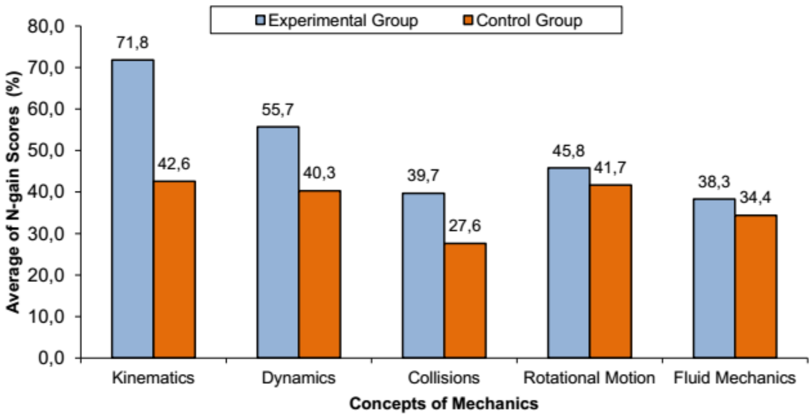

Figure 1. Comparison of the Improvement in Mechanics Concept Mastery for Both Sample Groups

In the concept of dynamics, some students have difficulty using appropriate frictional forces on several different issues. Generally, students have been able to recall the equations used in the calculations. Unfortunately, some students use the frictional force of the static maximum that has been calculated although the system has moved. This also occurs when they are asked to calculate the travel time of the objects that are dependent and connected with other objects through a pulley. The common error that occurs in both groups is that the acceleration value used by students is about 10 m/s2, whereas there should be an acceleration of the system used in the calculation. The misconceptions on this concept lead to errors in students' answers which continue throughout the solving of dynamic problems in mathematical calculations. The visualization and interactive charts that have been given to the experimental group students are sufficient in helping students understand this concept. This has led to the concept of dynamics experiencing a higher increase in the experimental group and the second highest increase recorded when compared to other concepts.

In the concept of the collision, students of both groups have a similar conceptual mastery on one-dimensional (1-D) collision. It is quite easy for the students of both groups to imagine the occurrence of the collision. Visualization has been provided through computer simulation to help students in solving each case. The same expressed by Hastuti, et al., (2016), that is, the use of computer simulations has a positive effect on problem-solving skills for the concept of momentum and impulses.

Students have difficulty solving cases related to 2D and 3D collisions. At a more complicated calculation, the mastery of the student decreased because there is an error during the writing of the value of the collided objects' velocity. Generally, the value of the velocity was directly written, just as the case with the 1-D collision, and was not expressed using the x-axis and y-axis components. Thus, consequently, all student answers are wrong. It is difficult for them to determine the direction of objects after 2-D collision. Experimental group students have the same experience. When students conduct their own virtual experiments through a simulation program, they finally find themselves important concepts to understand. Difficulties in this concept resulted in a low increase in the control group of 27.6% (low category).

The increase in conceptual mastery on the rotation material of both groups is similar. Both were in the medium category, that is 45.8% for the experimental group and 41.7% for the control group. Improvement in this category has helped Students to understand previous concepts of kinematics and dynamics.

Changes in kinematic symbols and dynamics for the straight motion to rotational motion are not difficult for students. Generally, students were able to solve cases in this section well. However, students' difficulties are shown in the material moment of inertia, torque, and others. Although the increase is in the medium category since it has been difficult to solve pre-test cases on this material. Interviews were conducted to determine the cause. Respondents were randomly selected in both groups. The information obtained is that there are too many variations of equations in this material with the different moment of inertia according to the type of object and its rotation axis. This result is consistent with the findings of Kim et al (2006), which states that it is too difficult to simulate the process in solids. We must be able to calculate the mass, the centre of mass, and the moment of inertia of the object. Utilization of computer simulations can help us to visualize geometry representations. Finally, students calculate the mass properties of each object displayed in graphical form more effectively. An image-based approach can be used in simulations, making computing the mass properties in geometry more efficient. Timberlake (2008) states that the use of computer simulations has been proven to be able to help students learn classical mechanics better than conventional through the approach of quantitative and analytical solutions to a classical model. Computer learning activities can also develop student skills in using computer simulations. In addition, the simulations that have been used by Kim et al (2006) are image-based approaches. However, it is more efficient to do mass properties in geometry which can be solved using graphs. In addition, Gunawan, et al (2014) found that the use of computer simulations can improve the students' mastery of physics concepts. Some of the concepts with a higher increase include optical geometry (58.2%), central force (68.8%), temperature and expansion (71.7%), and Coulomb law (68.6%). All of these materials are generally abstract concepts. This shows that visualization of the abstract concept is categorized as successfully helping students understand the concept better. In a concept dominated by mathematical equations, the improvement of conceptual mastery in the two classes did not differ significantly.

The lowest increase in the experimental group was on the sub-concept of fluid mechanics. The pre-test score is high in the experimental and control groups. This resulted in a low increase in the score of 'the students' mastery' of concept. In reality, even though the score is low, the student concept skill for both groups is high. The results of this study are supported by Nisrina, et al., (2016), who revealed that a learning that is based on virtual media has been able to improve students' conceptual mastery skills on static fluid materials.

Students' mastery of concepts has also improved in each sub-material of the fluid: hydrostatic main law, hydrostatic pressure, Pascal law, Stokes law, capillarity symptoms, and surface tension. Additional learning services are provided to improve the conceptual mastery to be used to solve post-test problems in this case. The students' high score for pre-test and post-test does not necessarily have a significant impact on the improvement of the 'conceptual mastery'.

Finkelstein et al (2005) have conducted research to test the effects of using computer simulations to substitute real laboratory tools in basic physics courses. This research involves three groups of students. The first group used the real lab tools, the second used computer simulation, and the last group had no laboratory experience. The three groups were compared in relation to their mastery of skills and physical concepts. The results showed that the mastery of physics concepts and skills of students who used computer simulation was higher than the two other groups involved in this study.

Perkins, et al (2008) has succeeded in empirically testing the effect of two lesson treatments (i.e., computer simulations and a real laboratory) using two types of tasks: structured and unstructured. It was found that the use of computer simulations is more effective in improving students' mastery of physics concepts. Dancy & Beichner (2006) argues that in addition to learning, simulations can be used to conduct assessments. Assessment through animation has further improved the 'mastery of physics concepts', compared to conventional tests. In addition, the animated assessment form provides more accurate measurement results without having to measure students' verbal skills. McIntyre, et al., (2008) revealed that computer simulation applications can be used for visualization, animation, calculation, reasoning and other packages. The program showed satisfactory results according to the purpose of the study. According to Landau et al (2004), the use of simulations is proven to be more efficient and accurate in calculating the physics variable values of matter in statistical physics.

Nevertheless, the use of computer simulations in learning must be done with good control. The lecturer should supervise the students in the classroom to facilitate and answer the questions asked after viewing the program. This is important because the different learning styles of students will affect the types of simulation programs used in learning. Gunawan, et al., (2016) found that the use of computer simulations helps visual-style students, whereas kinaesthetic-style students need to be given additional activities that involve psychomotor activity. Learning styles determine the student's strategy to succeed in learning, Habibi, et al., (2017).

It should be understood that computer simulations are not always relevant to be used to teach all kinds of physics concepts. Although mathematical equations are used as an integral part of the concept of physics, it must be explained gradually and procedurally to the students. Computer simulations are used to visualize physics concepts and processes that occur. Its use is not to replace the role of real laboratory activity, but to support it. Computer simulations are used for physics experiments, as well as an alternative to support lab tools for experiments in educational institutions, both in schools and higher education.

CONCLUSION

Computer simulation has successfully helped students to understand the concept of mechanics. The average score of student's concept mastery in the experimental group is higher than that in the control group. However, statistically, the improvement in the concept mastery in both groups did not differ significantly. Improvement in the mastery of concepts is higher in students who studied using computer simulations than those using conventional learning. The highest increase occurred in the concept of kinematics. In the concept of kinematics, experimental groups show high-category improvement. This means that computer simulations have helped experimental group students recall previous material better than conventional learning.

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