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# Harnessing technology-enabled active learning simulations (TEALSim) on modern physics concept

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**Abstract**. Technology-Enabled Active Learning Simulations (TEALSim) is a pedagogic innovation in learning by utilizing multimedia in the form of interactive simulations through active learning. In Indonesia, the use of TEALSim is still very poor. This study aims to identify the influence of the use of TEALSim in the learning of material physics of particle wave dualism at Makassar State University. This research is a quasi experiment using Nonequivalent Control Group Design. Data sources were obtained from the final test in the form of the Force Concept Inventory (FCI) and the Mechanics Baseline Test (MBT). The sample is two classes who programed introductory courses in quantum physics in the physics department of Makassar State University. The first is physics education class B with 25 students as experiment class and the second is physics education class C with 30 students. Data analysis is done descriptively and inferentially. Based on the results of data analysis, it was obtained information that there were significant differences between the FCI test results of the experimental class and the control class, whereas there were no significant differences in the results of the MBT test for both classes. It can be concluded that there needs to be another method in the use of TEALSim in order to be able to improve conceptual understanding, analytical skills, and mathematical skills

## 1. Introduction

Physics department at the Massachusetts Institute of Technology was the first institution using Technology Enabled Active Learning (TEAL) in 2011. One of the main characteristics of TEAL is rich in simulation software or visualization to facilitate learning. According to Dori and Belcher [1]. TEAL emphasizes the use of active learning and small groupings during the learning process. Class interactions and discussions are conducted through the Interactive Response System (IRS) that can permits the instructor or lecturer to ask questions, track and assess student responses to questions that are discussed individually and directly. the use of IRS makes it easy for both teachers and students from the beginning of learning to the final evaluation. The main purpose of TEAL is to make a learning format that involves students in learning physics and things related to technology more deeply so that they can obtain a more comprehensive understanding of the content under study, both conceptually and analytically [2]. Utilization fo TEAL integrates lectures, problem solving, and direct laboratory activities [3]. So hopefully students will be more active in participating in learning physics.

Because TEAL learning emphasizes observing physics concepts using technology, this is in accordance with the applicable curriculum. The current curriculum in Indonesia is the 2013 revised curriculum [4]. Some important points in learning according to K13 are learning with a scientific approach using several learning models characterized by experiments. In addition, the use of learning technology is also a major recommendation in this curriculum. So, to overcome the problems that caused the absence of observational activities in the laboratory and improve student success in science, some suitable alternative methods teaching science had been developed. For example, the use of computer visualization that attract students' attention is applied with certain learning models. However, to achieve that goal, one of the most important things is to prepare physics teachers who are able to teach well, master learning content and be able to use existing technology.

In learning physics in higher education, especially for prospective physics teachers it is very important to understand material conceptually and avoid misconceptions in abstract material material that can be found in modern physics [5]. There are several ways that can be done to improve conceptual understanding and reduce misconceptions, one of which is direct observation. However various constraints, the use of laboratories in universities such as not paying enough attention to safety in laboratory conditions [6], overcrowded laboratory spaces [7], problems in classroom management and lack of student background information on topics [8], lack of facilities or equipment laboratories owned by universities, risks in practicum in some materials and lack of instructions or instructions in using laboratories [9, 10].

So based on the description above, the researchers tried to apply one of the innovations in physics teaching, TEALSim. TEALsim was developed to provide an environment for physics students and physics instructors to make abstract concepts easier understandable, make invisible phenomena visible, enhance the conceptual understanding, allow live manipulation of parameters to make the immediate impact visible, and to provide an environment that is extensible by non-programming experts. Simulations should be easily scriptable by physics instructors and students, who are not used to complex programming languages. TEALSim learning has a difference compared to the original TEAL learning. In TEALSim learning experiments were not carried out directly integrated computers, this was due to the lack of equipment in the laboratory. In addition, the Interactive Response System used is Edmodo. Edmodo is one of the e-learning portals that is suitable for current learning, most of the discussion is done through this portal. By utilizing TEALSim, researchers want to identify whether there are significant differences between learning using TEALSim and conventional learning.

## 2.Methods

This type of research is a true experiment using The Randomized Posttest-Only Control Design. In this design there were two groups selected randomly, then given treatment using learning instrument based on TEALSim in the experimental class and conventional teaching in the control class then given the posttest to find out whether there were differences between the experimental group and the control group on particle wave dualism concept. The questions and duration of posttest work are the same for both classes. The tests used are divided into two, namely (1) Force Concept Inventory (FCI) developed by Hestenes, Wells, and Swackhamer [11], and (2) Mechanics Baseline Test (MBT) developed by Hestenes and Wells [12]. FCI consisting of several multiple choice questions, is used to measure students' conceptual understanding of the basic concepts. Whereas MBT, which consists of 6 description questions, is used to investigate mathematical or analytical manipulation abilities. All students involved in the study are scheduled to take the test in the same time slot.

The sample are two classes who programed courses introductory in quantum physics in the physics department of Makassar State University. The first is physics education class B with 25 students as experiment class and the second is physics education class C with 30 students. As for the place of trial for testing and data collection in the physics department of Makassar State University.

The research instrument used was an instrument of learning outcomes divided into two types of tests. The FCI test is given at the end of online learning. For black body radiation tests can be accessed at http://bit.ly/KuisRadiasiBendaHitam2019, for photoelectric effects accessed on the page http://bit.ly/xyzEfekFotolistrik, and for compton effects http://bit.ly/KuisEfekCompton2019 Whereas the MBT test is given collectively for 3 subjects and given at the end of the lesson and accessed through the http://bit.ly/2SGLXyU .

After the data is collected, the data are analyzed by descriptive statistics by using SPSS, the purpose of which is to find out the average student scores, standard deviations and class variances sampled. Written test scores are described in the form of a table and then assessed based on predetermined criteria. To test the hypothesis, the normality test and homogeneity test were carried out. If the data is declared normal and homogeneous then a T test is carried out to find out whether the hypothesis is accepted or rejected.

## 3. Result and Discussion

To see the learning outcomes data, two types of tests were carried out, namely the FCI and the MBT test. At the end of each subject, the two classes are given online-based tests. This test was developed specifically in this study. This test is made in the form of multiple choice. The tests developed represent each TEALSim-based learning goal to see understanding basic concepts. After careful examination of the results obtained as below:

**Table 1**. Statistics on the Score of FCI Test Results for Physics Students in Experimental Classes and Control Classes at Makassar State University

| Statistics | Result of FCI Test | |
|---|---|---|
| | **Experiment** | **Control** |
| Number of Samples | 26 | 21 |
| Highest Score | 91.75 | 76.35 |
| Lowest Score | 54.75 | 37.37 |
| Average | 76.8877 | 60.5314 |
| Standard Deviation | 9.60317 | 9.09124 |
| Variance | 92.221 | 82.651 |

Based on Table 1 it was found that the average score of the quiz results of the experimental class students taught using Technology Enavbled Active Learning was 76.8877 with a standard deviation of 9.60317 and a variance of 92.221 while the average score of the control class taught by conventional learning was 60, 5314 with a standard deviation of 9.09124 and a variance of 82.651. This shows that the average score of the experimental class quiz taught by using the Technology Enavbled Active Learning strategy is higher than the average score of the control class taught by conventional learning.

As for the description of the categorization of FCI test scores of the experimental class students and the control class in the graph below

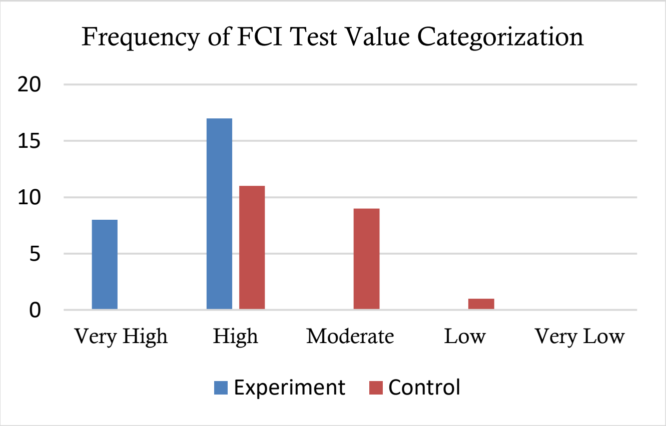


**Figure 1.** Comparation of Frequency oFCI Test Value Categorization

From the Diagram 1 above it can be seen that the majority of the scores of the two classes are in the "high" category for the experimental class as much as 17 and the control class as much as 11. For the very high category there are 8 for the experimental class and 0 for the control class. As for the "sufficient" and "low" categories for the control class 9 and 11 respectively, the experimental class 0. There were no respondents who had very low scores.

The FCI test data were then analyzed inferentially with t-test statistics aimed at testing the hypothesis. Before the t-test is carried out, a normality and homogeneity test is carried out as a t-test prerequisite. Based on the prerequisite test, the normality test with the Shapiro-Wilk equation (for a sample of < 50) obtained a significance value of 0.196 for the experimental class and 0.114 for the control class which means that both are greater than 0.05 so the two data are in the normal category. While the homogeneity test for the FCI test is 0.714 where the value is > 0.05, which means that both data are homogeneous. Thus to test the research hypothesis used parametric statistics, namely the t-test of two parties to obtain a significance value of 0,000, which means <0.05. Then it can be concluded that there are significant differences in the FCI test results between the experimental class and the control class.

An overview of the MBT test scores of experimental class physics students taught using Technology Enabled Active Learning Simulations and control classes taught by conventional learning are shown in the table below.

**Table 2.** Statistics on the Score of MBT Test Results for Physics Students in Experimental Classes and Control Classes at Makassar State University

| **Statistics** | **Result of MBT Test** | |
|---|---|---|
| | **Experiment** | **Control** |
| Number of Samples | 21 | 22 |
| Highest Score | 88.82 | 95.29 |
| Lowest Score | 34.71 | 25.59 |
| Average | 68.6555 | 68.1016 |
| Standard Deviation | 13.20653 | 16.25401 |
| Variance | 177.064 | 264.193 |

Table 2 shows that the average final test scores of experimental class physics students taught using the Technology Enavled Active Learning strategy of 68.655 with a standard deviation of 13.20653 and a variance of 177.064 while the average score of the final results obtained by students in the control class is 68,1016 with a standard deviation of 16,25401 and a variance of 264,193. This shows that the average score in the experimental class taught using the Technology Enavled Active Learning strategy does not have a significant difference compared to the average score obtained by students in the control class taught using conventional learning. As for the description of the categorization of MBT test scores of the experimental class students and the control class in the graph below

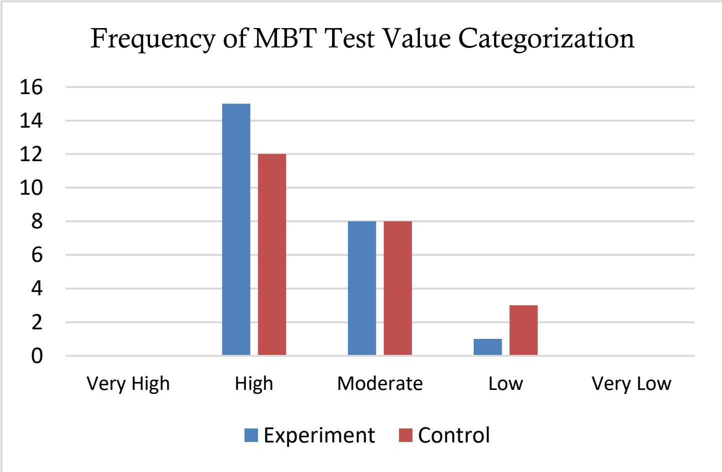


**Figure 2.** Comparation of Frequency of MBT Test Value Categorization

From the Figure 2 above it can be seen that the majority of the scores of the two classes are in the "high" category for the experimental class as much as 17 and the control class as much as 11. For the very high category there are 8 for the experimental class and 0 for the control class. As for the "sufficient" and "low" categories for the control class 9 and 11 respectively, the experimental class 0. There were no respondents who had very low scores.

The MBT test data were then analyzed inferentially with t-test statistics aimed at testing the hypothesis. Before the t-test is carried out, a normality and homogeneity test is carried out as a t-test prerequisite. Based on the prerequisite test, the normality test with the Shapiro-Wilk equation (for a sample of < 50) obtained a significance value of 0.238 for the experimental class and 0.058 for the control class which means that both are greater than 0.05 so the two data are in the normal category. While the homogeneity test for the MBT test is 0.704, where the value is> 0.05, which means both data are homogeneous. Thus to test the research hypothesis used parametric statistics, namely the two-party t-test so that it obtained a significance value of 0.904 which means> 0.05. Then it can be concluded that there is no significant difference in the results of the MBT test between the experimental class and the control class.

The learning process in the experimental class is carried out using the Active Learning Simulations Technology Enabled by providing worksheets that correspond to the six stages, namely 1) preparation; 2) mastery of basic understanding; 3) increasing conceptual understanding; 4) measurement of learning abilities; 5) consolidation stages (assignments). Viewed from the five stages, this learning can make the learning process no longer centered on the lecturer but on the student. Students also become more active and accustomed to thinking and discussing because there are physics-based simulation worksheets that are done in groups by requiring students to discover concepts and solve physical problems that require analysis. Student worksheets (MFIs) are equipped with observation and drawing steps so that all students participate during the learning process. Meanwhile, the implementation of learning in the control class, namely the lecturer provides material explanation directly and then provides training in the form of discussion of analytic questions.

Based on the descriptive analysis of the results of the conceptual understanding test (FCI) obtained significant differences from both classes. This is supported by Shie's research [13], which shows that the TEAL class significantly increases the test results of physics students' conceptual understanding after completing learning. There are differences in the results of the two classes because in the experimental class the use of Technology Enabled Active Learning Simulations is able to show students clearly the phenomena that occur related to the 3 sub-material provided. The behavior of abstract objects and their effects can be clearly observed through the interactive simulations presented. By using an MFI, students make observations in groups, write the results of these observations, determine the value of the quantities that exist and their relationships with each other. Questions in the MFI then help students to understand the basic concepts of each sub-material that exists. During the learning process, students follow learning well. In other words, the use of TEALSim has a positive impact on the ability of students at level C1 (knowledge) and C2 (understanding).

Whereas, based on descriptive analysis the results of analytical tests and mathematical manipulation ability (MBT) did not obtain significant differences from both classes. However, there are weaknesses in the use of the MBT test, namely the tests are held in the homes of each student so that the results of the analysis are in depth there is considerable cooperation between students so that the exact same values are obtained. In addition, one of the disadvantages of the MBT test with online description questions is that many student work documents are not sent in the system so they must be sent back through other systems. Therefore, in subsequent studies, it is better to take the MBT test in class simultaneously to minimize the level of student fraud in doing the test. Based on these results, it has not been concluded that the use of TEALSim has a significant influence on the ability of student application level (C3) and analysis (C4).

It should be noted that the findings reported in this study are based on data collected in one department. It cannot be concluded generally that the difference in research results between the experimental class and the control class is only due to the use of TEALsim only, but various other factors also affect. Some researchers argue that student effects, such as mathematical and physical preparation, attitudes and beliefs and teaching strategies, may greatly influence student learning outcomes from the courses being studied [13]. To draw more general conclusions, studies involve more students, lecturers, and researchers. In the future researchers can consider designing several experimental conditions, namely: (1) Use of TEAL; (2) active learning without technology; (3) direct learning without technology but accompanied by exercises and discussion of questions and (4) a combination of TEAL and direct learning. In addition, a number of researchers, such as Beatty, Gerace, Leonard, and Dufresne , regard the IRS as a tool for teaching promising physics. How to design adequate IRS questions to effectively engage students in higher-order thinking, not just as a "fun" tool, also needs to be explored further. Nevertheless, this study examines the performance of students in physics majors and hopes that the findings reported in this study will provide useful insights for those interested in adopting constructivist-oriented pedagogy established in a learning environment that supports technology.

## 4. Conclusion

Based on data analysis, it can be concluded that there are significant differences in the FCI test results of the experimental class with the control class. This is indicated by the value of the T test which is below 0.05. In other words, the use of the Technology Enabled Active Learning Simulations can make students have a high basic conceptual understanding. While based on data analysis, it can be concluded that there were no significant differences in the results of the MBT test in the experimental class with the control class. This is indicated by the value of the T test which is above 0.05. In other words, it cannot be concluded that the use of Technology Enabled Active Learning Simulations can make students have high analytical and mathematical skills. Because of that, it is necessary to have a detailed review and involve more samples to draw conclusions in general. in addition, there needs to be further research that collaborates on TEALSim learning and conventional learning especially in the practice of questions to see the effect on learning outcomes for all cognitive levels.

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