

Interactive conceptual instruction model assisted by PhET simulations on the improvement of physics multiple representations

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Abstract. This study aims to determine the effect of Interactive Conceptual Instruction (ICI) models aided by PhET Simulations on improving the ability of multiple representations of student's physics. The research method used was Pre-Experimental Design with One Group Pretest-Posttest design. Fifteen multiple-choice assessment instruments in the pre-test and post-test were given to 31 students of class 10th in SMA Negeri 1 Banguntapan. The results of the analysis state that there is an influence of interactive conceptual instruction models aided by PhET Simulations on improving the ability of multiple representations of student's physics. The improvement is shown by the Wilcoxon Sign Rank Test results. The results show that the significant value is smaller than the significant level (α), which is $0.000 < 0.05$. The mean value of the post-test is higher than the mean value of the pre-test shown in the descriptive analysis, and there is a shift in the range of values from 46-80 to 66-91. This research shows that interactive conceptual instruction models assisted by PhET Simulations can improve the ability of multiple representations of students physics.

Keywords: *PhET simulations, interactive conceptual instruction, multiple representations, physics*

1. Introduction

Achievement of competency standards in physics concepts contained in the physics learning curriculum that is students can apply physics concepts in everyday problems and can solve physics problems through appropriate concepts [1]. The ability to solve problems must be possessed by every student because one soft skill an important role in the learning process. In physics, there are some difficulties for students when solving problems, namely (1) difficulties in choosing and applying principles, (2) difficulties with formulas, (3) difficulties with physical values and quantities, (4) difficulties with graphs, and (5) difficulties with calculations [2]. Problem-solving in physics can be overcome with the help of the role of representation. Multiple representations that are often used in learning physics are verbal, picture, mathematical and graphic representations [3]-[6]. However, several studies have stated that the ability of multiple representation of students is still relatively low [7]-[9]. This is reinforced by the results of PISA in 2015 which showed that the mathematical ability and reading of Indonesian students ranked 63 and 64 out of 70 participating countries [10]. The results of other studies also present a profile of the ability of multiple representations of students based on mathematical representations, verbal, pictures, and graphics respectively are 80%, 71.4%, 34% and 22.9% [11]. Besides, some studies



present the error profile of multiple representations of physics. The percentage of errors based on verbal, physical, and mathematical representations were 73%, 89%, and 90%, respectively [12]. Therefore it is necessary to increase the ability of multiple representation of students.

Some studies emphasize to improve the representation ability of students as a basis for solving physics problems that have various representations [7], [13]. Several studies revealed that the presentation of concepts using various forms of representation significantly influenced the achievement of learning outcomes [2], [14], [15]. Representation has three functions, namely as a complement to help complete the cognitive process, as a barrier to interpretation to limit the possibility of misinterpretation, and as a constructor of students' understanding of the situation [16]. Development and improvement of representation ability can be trained in the learning process. The use of learning methods and supported by appropriate learning media can train students' representation abilities.

Several learning models can be applied in the learning process to improve the ability of representation. One of them is an Interactive Conceptual Instruction (ICI) model that was developed in 2001. This model was developed to support the development of students' thinking skills starting from the level of conceptual understanding. Understanding concepts requires interactive processes that provide opportunities to develop ideas, ideas or concepts through a process of dialogue and thinking [17], [18]. Interactive processes are contained in the stages of an interactive conceptual instruction model.

The interactive conceptual instruction model developed by Savinainen and used by several other researchers [17]-[20] has four stages, namely: (1) Conceptual focus, which focuses on students' attention on conceptual understanding. At this stage, the learning process begins with the provision of examples or demonstrations of real phenomena and/or problems that are often seen by students and related to the material being studied. Presentation of some representations contained at this stage such as pictures and verbal. (2) The use of texts is to provide opportunities for students to find various information about the material being studied through appropriate textbooks. This supports the students' interaction with the book to gain experience through understanding a text from the book that presents various representations to increase understanding. (3) Research-based material is to provide opportunities for students to conduct research or experiments based on concepts obtained from the conceptual-focused stage by working in groups. This process serves as a diagnostic tool to measure the understanding that has been achieved by students and overcome the difficulties encountered so that it can be used as a reference for further learning. At this stage, students are formed into heterogeneous groups to complete the Student Worksheet (LKPD) given by the teacher. Presentation of various representations such as pictures, mathematics, and graphics contained in the worksheet. (4) Classroom interaction, namely the process of interactions in the learning process, both between students or between students and teachers. Problems encountered in the experiment or learning process will be discussed by students with group members so that it causes peer learning. Peer learning is very important because the process of making critical decisions from the data obtained requires the thinking of several people to create complex problem-solving. In this process, the teacher functions as a facilitator, so that the process of interaction between the teacher and the students can still run. This stage encourages students to think through developed arguments and improve communication skills. From these stages, several other researchers used it by changing the order of the stages to suit class needs.

In addition to the learning model, the use of appropriate learning media can also help the learning process and support the process of increasing students' representation ability. Therefore we need a media that presents various forms of representation. In recent years the curriculum was developed by including computer-based and web-based learning media, including laboratory data collection and analysis systems [20]. The new perception of learning has changed from structured learning to modern learning processes for self-actualization [21]. Learners can learn from a variety of sources that are not limited to time and space. This is in line with the trend of the world change towards the industrial revolution era 4.0. If in the 1980s learning media used real tools and materials or three-dimensional teaching aids to visualize abstract concepts, now digital technology using software can be used to visualize concepts that are more effective, efficient and interactive and can be used at any time. Although it allows abuse by

students when using virtual media which is more preoccupied with trial and error features on the media compared to understanding the concepts of learning materials but can be minimized with the help of teachers [22], [23]. Implementing virtual media-assisted learning can also improve student learning outcomes, interests, and motivation at a lower cost than conventional learning media, make it easier for learners to learn wherever and whenever and improve students' skills in exploring learning media features to understand concepts physics. Although only reading the raw data presented by virtual media, but it can be a way to teach data analysis and make calculations using appropriate equations and practicing mathematical skills [24]-[27]. In contrast to the results of other studies, that there were no significant differences in student learning outcomes between classes given laboratory-based physics learning and computer-based physics learning [28].

Various virtual labs that have been developed specifically to support practical activities or experiments can be utilized in learning physics, one of which is Physics Education Technology (PhET) Simulations. The simulations contained in the PhET application can be used for learning physics, biology, chemistry, and mathematics [29]. This application can be used free of charge. Simulation is designed interactively, so users can use it easily [30]. Easy access and operation allow more high school students to use it with a little help from the teacher.

Some researchers have used PhET Simulations as a medium for learning physics. The results of the study show that the use of PhET Simulations can improve student learning outcomes both in cognitive and affective aspects compared to students who do not use PhET Simulations [31]-[33] and compared with students who use simple KIT [34]. Besides that, PhET Simulations also includes various representations such as static and dynamic images, mathematical and graphic. So that it hopes to stimulate the ability of multiple representations of students. The application of PhET Simulations can be applied to interaction conceptual instruction models because they contain a Research-based material stage, so the research process can be carried out through PhET Simulations media.

Based on the description that focuses on the low ability of multiple representations of students, it is necessary to research the influence of interactive conceptual instruction models assisted by PhET Simulations on the ability of multiple representations of students' physics. The purpose of this study is an interactive conceptual instruction model aided by PhET Simulations can improve the ability of multiple representations of students' physics.

2. Research method

The research method used is pre-experimental design with one group pre-test post-test design, as presented in figure 1 [35]. This method is used because of the limited permission in schools to research so that research can only be used in 1 class.

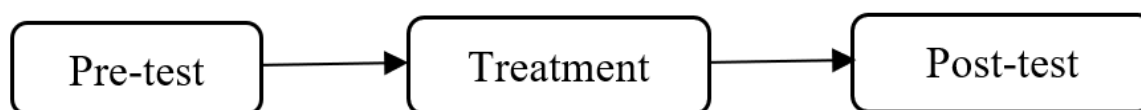


Figure 1. One group pre-test post-test design research design.

The study was conducted at SMA N 1 Banguntapan class 10th MIPA 4 in the 2018/2019 school year with a total of 31 students. The instrument in the form of a multiple-choice test consisting of fifteen questions was used to measure the ability of multiple representations. Pre-test dan Post-test use different but equivalent questions.

2.1. Preparation phase

The preparation phase is (1) School observations to determine time, school infrastructure and research samples, (2) making learning tools in the form of syllabus, lesson plans, and worksheet, (3) making indicators of research instruments, and (4) making research instruments.

2.2. Implementation phase

The implementation phase is (1) Validating the pre-test and the post-test questions, (2) validating the learning tools (3) giving pre-test in Class 10th MIPA 4 of SMA Negeri 1 Banguntapan, (4) giving treatment in the form of application of interactive conceptual models assisted by PhET Simulations, and (5) giving a post-test in class 10th MIPA 3 of SMA Negeri 1 Banguntapan.

Development of learning tools adapted to learning devices in SMA N 1 Banguntapan. Learning tools are feasible to use after being validated by teachers and expert lecturers. Table 1 presents a lesson plan with the interactive conceptual instruction model assisted by PhET Simulations. The lesson plan is designed for a one-time meeting with spring harmonic motion which is more focused on the spring period. Learning objectives are focused on the ability of multiple representations, so that the worksheet that is designed refers to the ICI model and contains verbal, picture, mathematical and graphic representations in accordance with the indicators of multiple representations in this study (table 2). The developed worksheet has several questions that are presented verbally and illustrated to direct students to make hypotheses about the factors that affect the spring period (table 3). The work steps presented guide students to conduct experiments on springs especially the spring period. The experiments were conducted in a virtual lab using PhET Simulations with the "mass and spring" experiment as presented in figure 2. The worksheet directs students to present the results of the data into mathematical and graphical representations so as to train the students' dynamic representation. The worksheet also presents questions at the end of the activity to guide students in making conclusions.


Table 1. Interactive conceptual instruction model assisted by PhET simulations.

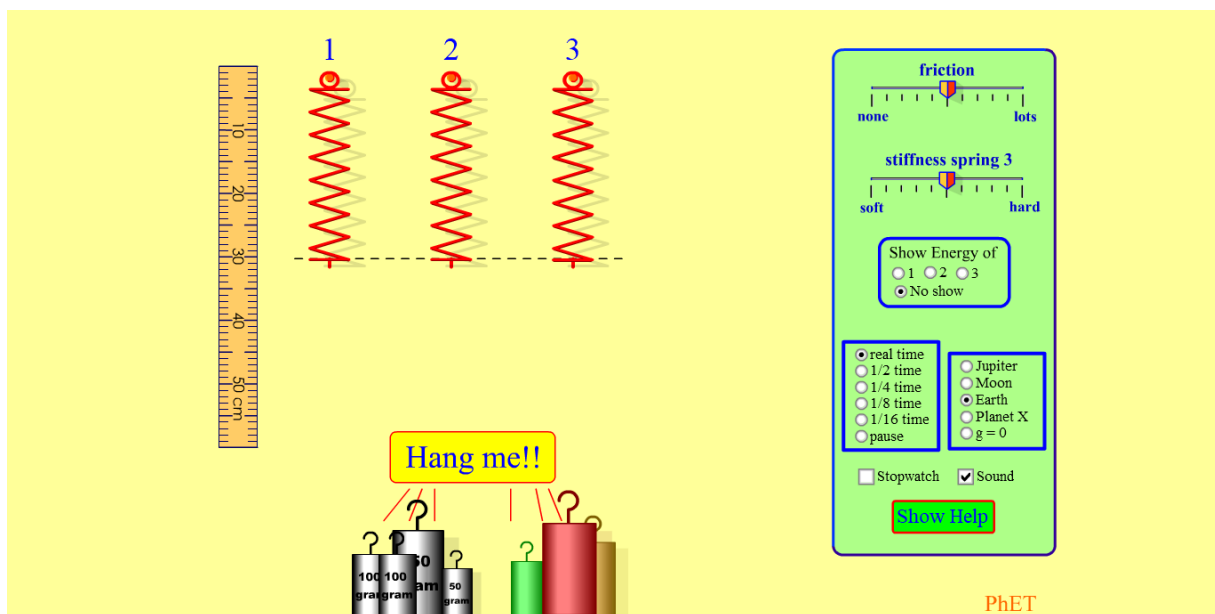
Syntax	Description	Learning objectives
Conceptual focus	Condition students to focus, provide motivation and apperception. Motivation and apperception <ul style="list-style-type: none"> - Students observe a video about the differences in the two spring swings for babies. - Students are directed to think from the questions given by the teacher, "What distinguishes the two swings? Why can a swing oscillate for several minutes with just one pull? Does the baby's weight affect the oscillation on the swing?" 	Interest and motivation to learn and independence of learning Stimulates mental representation
Classroom interactions	Organizing classes into groups, directing students to begin preparatory experiments through the application of PhET Simulations and worksheets, overseeing the division of tasks for each group.	Learning interactions are interdependent among group members
Research-based material	Learners answer questions as hypotheses about spring harmonic motion, students conduct "Mass and spring" experiments on PhET Simulations guided by a worksheet from the teacher, students analyze the data	Applying multiple representations, analyze through dynamic representations, understanding the concept of harmonic motion on a spring
Use of the texts	Students use textbooks to review the results of data analysis based on theory, students make conclusions based on the results of experiments and sources from textbooks	Conceptual understanding, applying multiple representations, learning through dynamic representation

Table 2. Indicators of multiple representations ability.

No.	Indicators
1.	Re-present the concept in verbal representations
2.	Re-present the concept in image representation
3.	Re-present the concept in mathematical representation
4.	Re-present the concept in graphical representation

Table 3. List of questions to form students' hypothese.

No.	Questions
1	 <p>When you pull the swing down, the swing will move back and forth (top-down) without the need to be pulled again.</p> <p>What concept is applied in the use of the swing?</p>
2	What happens if you get on the swing? Assuming the height is set with the baby's weight.
3	In your opinion, do each springs have different strengths to do harmonic motion?
4	If the swing is assumed can lift a very large load, including you. Will there be a time difference to travel 1 vibration (one-time movement from top to bottom) between the swing that lifts the baby and the swing that lifts you. Is it the same or one of them moving slower? Explain!

**Figure 2.** Mass and spring PhET simulations.

Before the learning implementation, students are given a pre-test to determine the initial conditions of students before being given treatment. Giving a post-test is carried out after the learning process with an interval of 3 days. The test instrument provided contains verbal, picture, mathematical and graphic representations. The test instrument was validated by the expert and the results of validity were analyzed using V-Aiken analysis [36]. The results of the V-Aiken analysis of each item are in the range of 0.85-0.91 from a maximum score of 1 so that each item is included in the very valid category and is suitable for use.

2.3. Final phase

The final phase is 1) Analyzing data obtained from the results of the pre-test and post-test using descriptive statistical analysis, normality test, and Wilcoxon Sign Rank Test with a significance level of 5%. Wilcoxon Sign Rank Test is used to determine whether there is the effect of treatment on the samples that are interconnected with normally distributed data [37], 2) Describe the results of data analysis and draw conclusions based on data analysis.

3. Results and Discussion

This research focused on the influence of interactive conceptual models aided by PhET simulations on the improvement of multiple representations of student's physics. Learning is given to the simple harmonic motion material in the spring through the practicum activities "masses and spring" contained in PhET simulations. In learning, lesson plans are applied that have been developed with an interactive conceptual model through a scientific approach, Student Worksheet for practicum activities and the use of PhET simulations through the laptops of students in groups.

The distribution and comparison of the values are pre-test and post-test presented in figure 3. The results of the pre-test and post-test were analyzed using the SPSS application to produce descriptive statistics presented in table 4, the normality test presented in table 5 and the test Wilcoxon Sign Rank tests are presented in table 6.

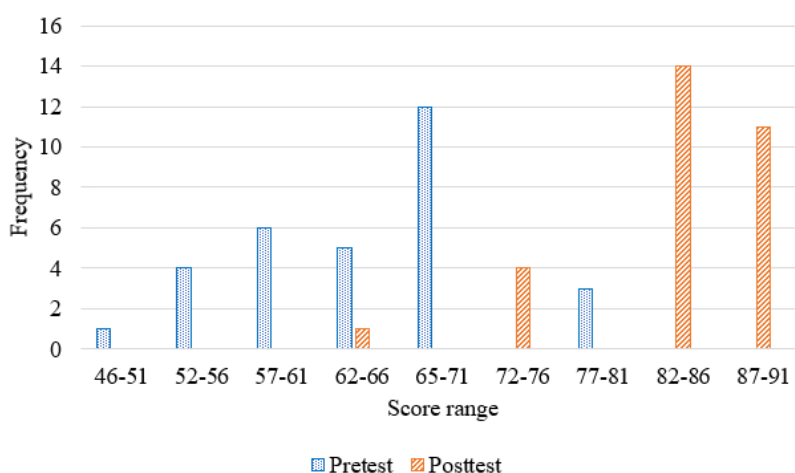


Figure 3. Distribution of scores on the pretest and posttest ability of multiple representations of physics class 10th MIPA SMA Negeri 1 Banguntapan.

Table 4. Descriptive statistics.

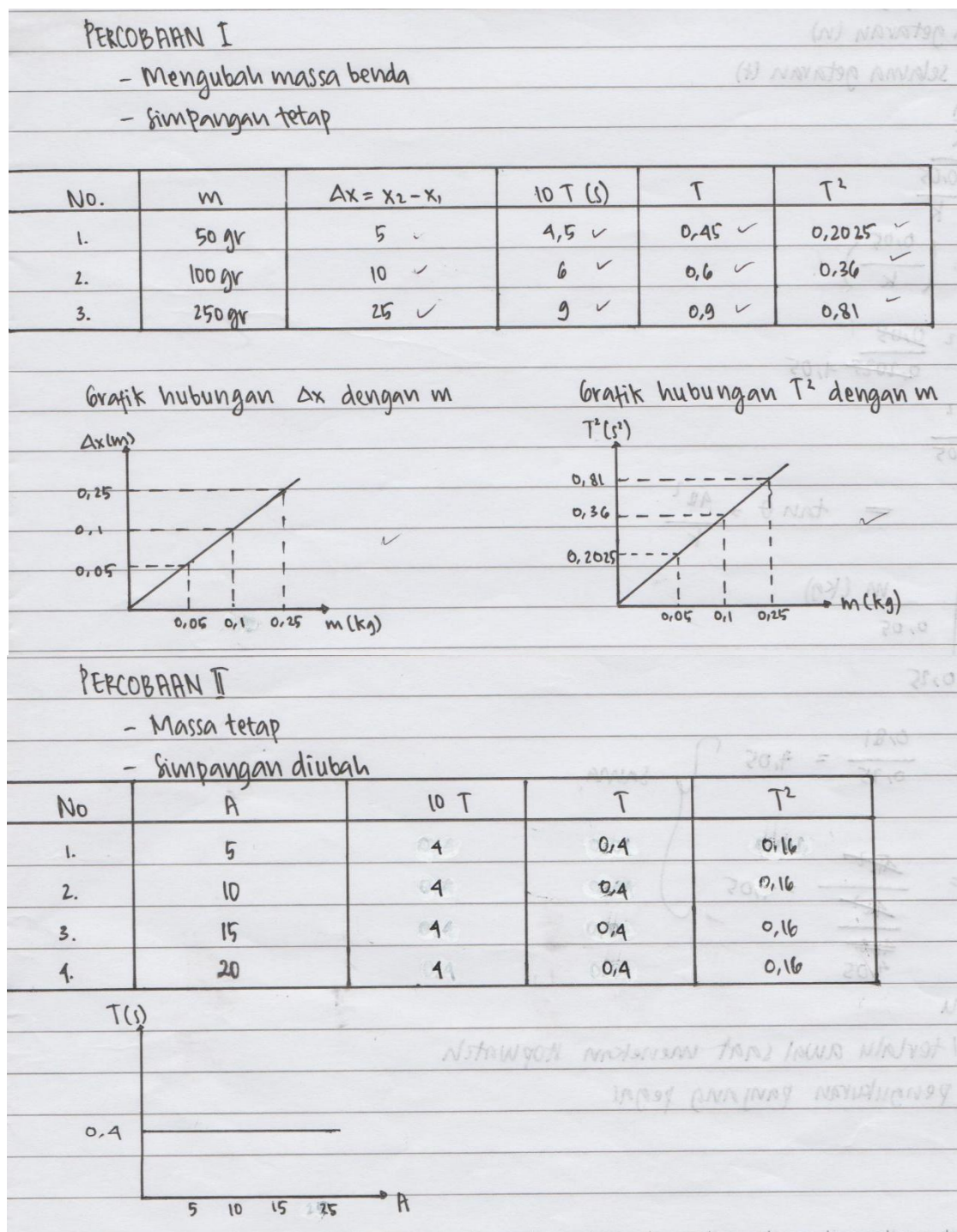
	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	31	46	80	66.58	9.051
Posttest	31	66	91	84.26	6.324
Valid N (listwise)	31				

Table 5. Normality test.

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.245	31	0.000	0.905	31	0.010
Posttest	0.260	31	0.000	0.813	31	0.000

Table 6. Results of the wilcoxon sign rank test.

Null Hypothesis	Test	Sig.	Decision
The median of differences between pretest and posttest equals 0	Related sample- wilcoxon sign rank test	0.000	Reject the null hypothesis

**Figure 4.** Results of analysis of experimental data.

1. Perhatikan Tabel 1 secara seksama, ketika beban m diperbesar, apa yang terjadi dengan periode getaran? Apakah kesebandingan antara periode (T) sebanding dengan massa (m) yang diperoleh dari percobaan sesuai dengan teori?

Periode getaran yang terjadi sangat dipengaruhi oleh massa beban dan konstanta pegas. Sehingga pada saat massa beban diperbesar, periode getaran juga akan semakin besar, begitu pula sebaliknya, pada saat massa beban diperkecil, periode getaran juga akan semakin kecil. Hal ini dapat dibuktikan berdasarkan rumus cara mencari Periode (T) jika diketahui massa beban (m) dan konstanta pegas (k), yaitu $T = 2\pi \sqrt{\frac{m}{k}}$

2. Perhatikan Tabel 2 secara seksama. Apakah periode pegas dipengaruhi oleh amplitudo?

Periode (T) pegas tidak dipengaruhi oleh amplitudo (A) karena periode itu dipengaruhi oleh massa beban (m) dan konstanta pegas (k). Hal ini terbukti dari grafik II (Perbandingan antara T dengan A yaitu membentuk garis lurus horizontal yang artinya amplitudo (A) tidak mempengaruhi periode pegas (T)

3. Faktor-faktor apa saja yang mempengaruhi periode getaran pegas?

Faktor yang mempengaruhi periode getaran pegas, yaitu waktu (t), massa (m), simpangan getaran (x), konstanta pegas (k)

Figure 5. Students' answers in term of verbal representations.

4. Secara matematis, menggunakan $T = 2\pi \sqrt{\frac{m}{k}}$ hitung tetapan pegas berdasarkan Tabel 1.

$$T = 2\pi \sqrt{\frac{m}{k}}$$

$$k = \frac{m \cdot 4\pi^2}{T^2}$$

Tetapan pegas (k) berdasarkan tabel 1

1) Diketahui : $m = 0.05 \text{ kg}$ $T = 0.189 \text{ s}$
 Ditanya : k ?
 Dijawab : $k = \frac{m \cdot 4\pi^2}{T^2}$
 $= \frac{0.05 \cdot 4\pi^2}{0.189^2}$
 $= \frac{200\pi^2}{189} \approx 10.44403 \text{ N/m}$

2) Diketahui : $m = 0.1 \text{ kg}$ $T = 0.397 \text{ s}$
 Ditanya : k ?
 Dijawab : $k = \frac{m \cdot 4\pi^2}{T^2}$
 $= \frac{0.1 \cdot 4\pi^2}{0.397^2}$
 $= \frac{400\pi^2}{397} \approx 9.94419 \text{ N/m}$

3) Diketahui : $m = 0.25 \text{ kg}$ $T = 0.980 \text{ s}$
 Ditanya : k ?
 Dijawab : $k = \frac{m \cdot 4\pi^2}{T^2}$
 $= \frac{0.25 \cdot 4\pi^2}{0.980^2}$
 $= \frac{50\pi^2}{49} \approx 10.07102 \text{ N/m}$

Figure 6. Students' answers in terms of mathematical representation.

The statistical description results in table 4 show an increase in the mean value of the pre-test and post-test, i.e., from 66.58 to 84.26. The range of values obtained by students shifted from 46-80 to 66-91. The value shift is shown significantly in figure 3, the frequency of students' post-test scores is more in the right area of the graph, while the frequency of students' pre-test values is more in the left region

of the graph. Besides being reviewed descriptively, the data were also analyzed through inferential statistics.

The data distribution is not normally distributed based on the SPSS output shown in table 5. The study subjects numbered 31 students, so the normality test uses Shapiro Wilk. The results of the analysis on Shapiro Wilk showed significant values at the pretest and posttest were smaller than α , namely $0.01 < 0.05$ (pretest) and $0.00 < 0.05$ (posttest). These criteria state that the data distribution is not normally distributed, so the next analysis uses a nonparametric analysis, the Wilcoxon Sign Rank Test.

The results of the analysis Wilcoxon Sign Rank Test in Table 6 show that the significant value is smaller than α , i.e., $0.000 < 0.05$. These criteria state that alternative hypotheses are accepted, namely interactive conceptual instruction models aided by PhET Simulations have an effect on increasing the ability of multiple representations of students physics. The effect that occurred was positive as indicated by the mean value of the pre-test of 66.58 lower than the mean value post-test of 84.26 with a difference of 17.677.

In addition to the results of the pretest and posttest, the results of the worksheet also showed the ability of multiple representations of students. The results of data analysis conducted by one of the groups are presented in Figure 4. Students can switch from one representation to another or known as dynamic representation. Students translate mathematically into a graph, even though the graph created still has shortcomings such as the scale on the graph. Presentation of PhET Simulations also trains the ability of image representation. Static and dynamic images are presented in the "mass and spring" experiment in PhET Simulations [30] (figure 2).

The questions given at the end of the activity lead students to find conclusions. This is done to avoid widening the conclusion. Students often cannot understand the relationship between the purpose of the experiment and the results of the experiment obtained. Students only carry out experiments according to the guidelines without understanding what they are doing [38]. Therefore, questions are presented so that students can connect the results of the experiment with the purpose of the experiment. In this phase, students are expected to use textbooks to support the experimental data and answer questions.

Figure 5 and figure 6 present students' answers based on questions directed to determine conclusions. Some are presented verbally and some are presented mathematically. Based on Figure 5, students can process sentences into a conclusion based on concepts obtained from textbooks. Learners can connect concepts and theories with the results of experiments. Presenting it in a verbal representation and can be conveyed well. Based on figure 6, students can use mathematical representation with directed steps and can be conveyed properly.

The results of the experimental activities show that students can present various representations and can implement dynamic presentations. The representation presented can be understood by the reader and structured.

The results of the overall analysis state that interactive conceptual instruction models aided by PhET Simulations can improve the ability of multiple representations of students physics. The interactive processes contained in the interactive conceptual instruction model allow students to develop ideas, ideas or concepts through a process of dialogue and thinking [31],[32]. The learning media used also plays a role in the learning process. PhET Simulations present simulations with various representations such as static and dynamic images, audio, graphics and data presentation in tabular form. The display can stimulate students to process data in a variety of representations and practice the ability of multiple representations to improve student learning outcomes. This is in line with several studies which state that PhET Simulations can improve student learning outcomes from both cognitive and affective aspects [32],[33],[39]. The use of representation is an essential component in the process of science communication [40]. Increasing the ability of multiple representations can improve the ability to solve physical problems and understanding concepts because of the involvement of many mental images [41],[42], besides, the representation acts as an aid in solving physical problems [7],[13].

4. Conclusion

This article presents the effect of interactive conceptual instruction models assisted by PhET Simulations on improving the ability of multiple representations of student's physics. The results showed that the interactive conceptual learning model aided by PhET Simulations applied had a positive effect on increasing the ability of multiple representations of student's physics. The interactive processes contained in the learning model provide opportunities for students to be able to further develop ideas and interpretations accompanied by a dialogue process. PhET Simulations which have a variety of interpretations can practice the representation ability of students.

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