JPPIPA 9(10) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Effect of Interactive Conceptual Instruction Assisted by PhET Simulations on the Student's Scientific Consistency in Physics

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Received: August 9, 2023
Revised: September 4, 2023
Accepted: October 25, 2023
Published: October 31, 2023

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DOI: 10.29303/jppipa.v9i10.5193

Abstract: This study aims to determine the effect of Interactive Conceptual Instruction Assisted by PhET Simulations on students' scientific consistency. The research method used was quasi experiment with the matching-only pretest-posttest control group design involving 62 students in one of the high schools in Indonesia. The instrument used was an scientific consistency test modified from the Representational Variant of Force Concept Inventory (R-FCI). The data obtained were analyzed by t-test and N-Gain. The results showed that Interactive Conceptual Instruction Assisted by PhET Simulations can improve students' scientific consistency.

Keywords: Interactive conceptual instruction; PhET; Physics; Scientific consistency; Simulations

Introduction

Conceptual understanding is a crucial aspect of science learning as it enables students to develop a deep understanding of scientific concepts, transfer their knowledge to new situation, and utilize acquired scientific knowledge in order to explain and interpret everyday facts (Addido et al., 2022; Echempati, 2014; Schwortz & Burrows, 2021). Conceptual understanding is an important variable to fulfill before progressing further in learning (Handhika et al., 2017). It involves equipping students with the necessary skills to comprehend and interpret scientific ideas, allowing them to build on their knowledge and apply it creatively (Addido et al., 2022). Conceptual understanding goes beyond mere memorization and encourages students to formulate their own ideas and ask questions based on their understanding (Anim-Eduful & Adu-Gyamfi, 2022).

Scientific consistency is another important aspect of science learning. It refers to the internal consistency and explanatory power of scientific theories and concepts. A synthetic conception combines intuitive understandings with scientific information in a way that shows concern for internal consistency and explanatory power (Vosniadou, 2019). By promoting scientific consistency, students can develop a more robust understanding of scientific concepts and theories.

A solid conceptual understanding can be marked by scientific consistency, where students can correctly and consistently solve conceptual problems using various different representations for the same context. The use of these various representations is necessary to support students' understanding ability (Campos et al., 2020; Resita & Ertikanto, 2018; Rosengrant et al., 2009). Students with a strong conceptual understanding will demonstrate good scientific consistency as well (Sriyansyah et al., 2015). Therefore, students who possess scientific consistency not only master

How to Cite:
Furqon, M. (2023). The Effect of Interactive Conceptual Instruction Assisted by PhET Simulations on the Student's Scientific Consistency in Physics. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8040–8050. https://doi.org/10.29303/jppipa.v9i10.5193

representational skills but also have a correct, robust, and consistent conceptual understanding.

In the ever-evolving landscape of education, innovative pedagogical methods have emerged, driven by the integration of technology and modern teaching strategies (Huda et al., 2019). Interactive Conceptual Instruction (ICI) is an approach developed to improve students' conceptual understanding (Kaniawati et al., 2021). Interactive conceptual instruction aims to enhance students' understanding of complex concepts through interactive and visual learning experiences. This approach utilizes various technologies, such as computer simulations, animations, and videos, to provide students with opportunities to actively engage with the content and develop a deeper understanding of the concepts (Kaniawati et al., 2021; Ndihokubwayo et al., 2020; Özcan et al., 2020).

The use of technology, such as computer simulations and animations, is particularly beneficial in interactive conceptual instruction. These technologies provide visual representations of complex and abstract concepts, making them easier for students to understand (Johan et al., 2018; Özcan et al., 2020). Visualization and animation techniques have been shown to improve students' comprehension and conceptual understanding in various subjects, including physics (Ayu et al., 2021; Fakhriyah et al., 2022; Johan et al., 2018; Özcan et al., 2020; Saputra & Mustika, 2022; Vidak et al., 2020). Furthermore, simulations allow students to interact with the content, manipulate variables, and observe the outcomes, which can enhance their learning experience and facilitate conceptual changes (Hannel & Cuevas, 2018; Özcan et al., 2020).

One of computer simulation that has gained significant attention is the PhET Interactive Simulations. PhET (Physics Education Technology) is a collection of free online simulations developed by the University of Colorado Boulder that allows students to interact with virtual environments and explore scientific phenomena (Zulkifli et al., 2022). PhET simulations have been widely used in physics education to support learning and enhance students' understanding of various concepts. These simulations aim to bridge the gap between abstract concepts and real-world applications, providing students with an opportunity to actively engage with physics principles. The use of interactive simulations like PhET holds great potential for improving conceptual understanding in physics education.

PhET offers a powerful tool for visualizing abstract concepts, exploring physics phenomena, and promoting active engagement in the learning process (Johan et al., 2018; Kaniawati et al., 2021; Ndihokubwayo et al., 2020; Saudelli et al., 2021). PhET interactive simulations have been reported to improve explanations of abstract concepts in physics and promote learners' thinking abilities (Salame & Makki, 2021). The simulations provide a better understanding of science learning concepts and help students develop critical thinking skills (Khaeruddin & Bancong, 2022). Additionally, the use of PhET simulations has been found to increase students' interest and motivation in the subject (Ismalia et al., 2022; Prasetya et al., 2022). Through the synergy of ICI with PhET simulations, a novel dimension is added to this instructional paradigm, aiming to bolster students' scientific consistency within the domain of physics. The use of ICI with computer simulations has also been shown to improve students' learning outcomes in terms of cognitive and affective aspects (Patriot & Jannah, 2022).

Despite the growing interest in integrating technology into science education, there is a need for empirical research that systematically investigates the impact of incorporating PhET simulations into instructional practices. While anecdotal evidence suggests positive outcomes, rigorous studies examining the effect of interactive conceptual instruction assisted by PhET simulations on students' scientific consistency in physics are relatively limited. Addressing this gap is essential to provide educators with evidence-based insights into the potential benefits and challenges of using PhET simulations in physics classrooms.

The primary aim of this study is to investigate the effect of interactive conceptual instruction assisted by PhET simulations on improving students' scientific consistency in physics. By incorporating these interactive instructional methods into the classroom setting, we seek to determine if they lead to more consistent application of fundamental physics principles among students.

This research study will contribute valuable insights into the effectiveness of using PhET simulations as an instructional tool for enhancing student learning outcomes in physics education. Additionally, it will provide evidence-based recommendations for educators looking to incorporate interactive conceptual instruction methods into their teaching practices.

Method

Research Methods and Participants

The method used in this research is a quantitative method. This research is a quasi-experiment with a pretest-posttest group design that refers to Creswell and Guetterman (Creswell, 2019). The participants consisted of 62 high school students from one of the public schools in Indonesia. The participants were divided into two groups: the control group consisting of 30 students and the experimental group consisting of 32 students. The sampling method employed in this study was purposive sampling. The selection of participants was based on specific criteria that aligned with the research objectives. The selection criteria used in this study involved finding participants who were in the same grade and had never previously received interactive conceptual instruction in physics with PhET simulations. The design in this research is presented in Figure 1.

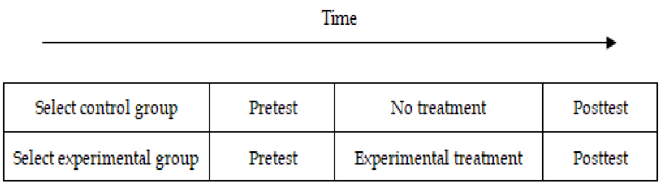

Figure 1. Pretest and posttest group design

Data Collection and Instruments

To measure students' scientific consistency, pretest and posttest data were collected. The instrument used in the data collection is an scientific consistency test modified from the Representational Variant of Force Concept Inventory (R-FCI) by Nieminen et al. (2010). The test of understanding ability is in the form of 27 multiple choice questions on Newton's Law material which includes five concepts and four types of representational modes: verbal, pictorial, graphical, and mathematical. The distribution of these questions is presented in Table 1.

Table 1. Level of Critical Thinking Skills

Concepts	Representation Mode	Item Number(s)
Minimum Force Required for Movement	Verbal, Graphical, and Mathematical	1, 10, 19
The Relationship Between Mass and Inertia	Verbal, Graphical, and Mathematical	2, 11, 20
The Relationship Between Force and Acceleration (I)	Verbal, Graphical, and Mathematical	3, 12, 21
The Relationship Between Force and Acceleration (II)	Verbal, Graphical, and Mathematical	4, 13, 22
The Relationship Between Force and Acceleration (III)	Pictorial, Graphical, and Mathematical	5, 14, 23
The Relationship Between Mass and Acceleration (I)	Verbal, Graphical, and Mathematical	6, 15, 24
Between Mass and Acceleration (II)	Pictorial, Graphical, and Mathematical	7, 16, 25
The Relationship Between Action and Reaction Forces (I)	Pictorial, Graphical, and Mathematical	8, 17, 26
Between Action and Reaction Forces (II)	Pictorial, Graphical, and Mathematical	9, 18, 27

The test has been validated by experts and tested in the field to determine its validity before being used in research. Validation was conducted using the Content Validity Index (CVI) method involving five experts in the fields of physics content, physics learning, and learning evaluation. CVI is used to measure the content validity of the question items as a whole. The validation results using the CVI method resulted in an index value of 0.90 which is categorized as medium validity based on Irawan et al. (2020), meaning that the test is valid with a medium level. Meanwhile, the field test to determine the reliability of the test using the KR-20 method resulted in an index of 0.77 which is categorized as good reliability based on Sutrisno (2016), meaning that the test is reliable which is categorized as good.

Data analysis

The data in this study are quantitative data in the form of scores derived from pretests and posttests. In the scientific consistency test, the scoring of each theme consisting of three questions with different forms of multirepresentation, refers to the rules used by Nieminen et al. (2010) as presented in Table 2.

Table 2. Level of Critical Thinking Skills

Score	Criteria
2	If the student chooses three related and scientifically correct answers within the same theme
1	If the student chooses two related and scientifically correct answers within the same theme
0	If students choose unrelated and scientifically correct options within the same theme

To determine the level of scientific consistency of each student in the entire test, the average score for all themes was calculated. Student scores for all themes were summed and then divided by the number of themes, so that the average score was in the interval 0 to 2. Furthermore, the average score was converted into an average on a scale of 0 - 100 using the formula:

$$\text{Student score} = \frac{\text{Total score gained}}{\text{Maximum score}} \times 100\% \quad (1)$$

Based on the average score and value, students' scientific consistency was categorized into three levels of consistency Nieminen et al. (2010) as presented in Table 3.

Table 3. Level of Scientific Consistency

Level	Average Score	Average Converted Score	Category
I	$1.7 \geq SC \geq 2.0$	$85 \geq SC \geq 100$	Consistent
II	$1.2 > SC > 1.7$	$60 > SC > 85$	Moderately consistent
III	$0 \geq SC \geq 1.2$	$0 \geq SC \geq 60$	Inconsistent

To determine the effect of interactive conceptual instruction assisted by phet simulations on the student's scientific consistency in physics, a mean difference test was conducted. Before testing the average difference in scores between the experimental and control groups, a normality test was first carried out to determine whether the data was normally distributed or not. In this study, the normality test of the research data was carried out using the Kolmogorov-Smirnov test. In normality testing with the Kolmogorov-Smirnov test, normally distributed or abnormally distributed data can be known by comparing the calculation results (D_{max}) with the critical value of the Kolmogorov-Smirnov test (D_{table}) . If $D_{max} \leq D_{table,}$ then the data is normally distributed and vice versa. The confidence level used is 95%. If the data is not normally distributed, the statistics used to test the mean difference is a nonparametric test.

Furthermore, a homogeneity test was conducted to determine whether the data had the same variance. If the data has the same variance, it can be interpreted that the data comes from the same population or the same characteristics. If the data is normally distributed, the data will then be tested for homogeneity with the Bartlett test. However, if the data is not normally distributed then the data will be tested for homogeneity with the Levene test. In testing homogeneity with Bartlett's test, homogeneous data or inhomogeneous data can be known by comparing the calculation results ($\chi^2{}_{count}$) with the value in the table $\left(\chi^2{}_{table}\right)$. If $\chi^2{}_{count} \leq \chi^2{}_{table}$, then the data is homogeneous.

After the normality and homogeneity tests are carried out, the next stage of data analysis is the mean difference test. The mean difference test aims to determine the significance of the difference between the two means. If the average is normally distributed and homogeneous, then the test of the difference in the average data is done using the t test. Meanwhile, if the data are not normally distributed, the test for differences in the mean data is carried out using the Mann-Whitney test. In testing the average difference with the t test, the t_{count} and t_{table} values are compared. If $t_{count} > t_{table}$ then there is a significant difference between the two data and vice versa.

Furthermore, to determine the improvement of students' scientific consistency after applying interactive conceptual learning assisted by PhET simulation, a normalized gain analysis of the pretest and posttest results was carried out. The normalized gain value is calculated using the following formula from Hake (1998).

$$(g) = \frac{\%\ \text{posttest} - \%\ \text{pretest}}{100 - \%\ \text{pretest}} \quad (2)$$

According to Hake (1998), the results of the normalized gain calculation are divided into three categories as presented in Table 4. Besides being carried out as a whole, the analysis of students' scientific consistency will also be carried out based on the mode of representation. This aims to determine the picture of the increase in each mode of representation. The increase in scores in each mode of representation will also be analyzed using N-Gain.

Table 4. Category of N-Gain Score

N-Gain Score	Category
$0.70 \leq (g) \leq 1.00$	High
$0.30 \leq (g) < 0.70$	Medium
$0.00 < (g) < 0.30$	Low

Result and Discussion

Implementations of Interactive Conceptual Instruction Assisted by PhET Simulations

Interactive Conceptual Instruction Assisted by PhET Simulations applied in this study is a learning model that constructs and instills concepts firmly through effective interaction and uses various representations assisted by PhET simulations on Newton's Law material. The stages carried out in the learning process by applying Interactive Conceptual Instruction Assisted by PhET Simulations include orientation which consists of concept focus features, concept embedding which consists of concept focus features and class interaction, concept reinforcement which consists of class interaction features and research-based teaching materials, and review which consists of text usage features.

In the first stage, namely orientation, the teacher conducts apperception through questions to recall the previous material that has been learned. Furthermore, the teacher motivates students through the presentation of a video of an event related to Newton's Law material. The teacher then asks questions to students related to the video presented.

In the second stage, which is conceptualization, the teacher conducts a demonstration related to the concept of Newton's Law being taught. The teacher asks questions to students related to the demonstration. Then the teacher divides students into small groups and guides students to conduct experiments using PhET Simulations to answer questions related to the demonstration with the PhET Simulations-based

Worksheets guide. Next, the teacher directs students in groups to discuss the results of the Newton's Law experiment. After that, the teacher directs students in groups to conclude the results of the Newton's Law experiment. Next, the teacher asks representatives of student groups to present the results of the Newton's Law experiment. Then the teacher gives the opportunity to other student groups to respond to the answers of the student groups who come forward.

In the concept reinforcement stage, the teacher explains the relationship between variables in Newton's Law verbally, graphically, and mathematically. Then the teacher explains the cause of the event in the video that has been presented and the demonstration that has been done using the concepts in Newton's Law. Next, the teacher directs students in groups to discuss working on problems related to concepts in Newton's law Active Learning Problem Sheets (ALPS) based on PhET Simulations using concepts in Newton's Law. After that, the teacher directs students in groups to discuss answering ALPS questions. The teacher then discusses the questions in the ALPS and provides an opportunity for students to ask about the discussion of questions in the ALPS that have not been understood.

In the review stage, the teacher directs students to conclude the lesson on Newton's Law on that day. Then the teacher directs students to record the concepts in Newton's Law that have been learned. Next, the teacher gives practice questions to students in the form of formative test questions about Newton's Law. After that, the teacher gives structured assignments to students, namely resumes and concept maps of Newton's law material. Finally, the teacher tells students the material that will be learned next.

Comparison of Student's Scientific Consistency in Physics

The normality test of students' scientific consistency data was conducted using the Kolmogorov-Smirnov test at the 95% confidence level. The results of the normality test of the ability to understand data are presented in Table 5.

Table 5. The Normality Test Result of Scientific Consistency Data

D value	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
D_{max}	0.214	0.093	0.160	0.217
D_{table}	0.234		0.242	

From Table 5, it can be seen that each D_{max} value for the pretest and posttest data of scientific consistency in the experimental group as well as the pretest and posttest data of scientific consistency in the control group is smaller than the D_{table} value. Therefore, it can be concluded that the four groups of data come from a normally distributed population.

The homogeneity test of students' comprehension ability data was conducted using Bartlett's test at the 95% confidence level. The results of the homogeneity test of the scientific consistency data are presented in Table 6.

Table 6. The Homogenity Test Result of Scientific Consistency Data

χ^2 value	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
χ^2_{count}		1.297		0.594
χ^2_{table}		3.841		

From Table 6, it can be seen that each value of χ^2_{count} for pretest and posttest data of scientific consistency in the experimental group as well as pretest and posttest data of scientific consistency in the control group is smaller than the value of χ^2_{table}. Therefore, it can be concluded that both pairs of data have homogeneous variances.

Based on the results of the normality test and homogeneity test of the scientific consistency test data, it is known that the data come from a population with normal distribution and both classes have homogeneous variances. Therefore, the research hypothesis test was carried out by testing the difference in the mean scores of the scientific consistency of the experimental group and control group students both on the pretest and posttest using the t test. The results of the test for the difference in the mean scores of the scientific consistency of the two classes are presented in Table 7.

From Table 7, it can be seen that the t_{count} value for the pretest of scientific consistency in both classes is smaller than the t_{table} value. Therefore, it can be concluded that the average score of scientific consistency between the experimental group and the control group is not significantly different on the pretest. Meanwhile, the t_{count} value for the posttest of comprehension ability in both groups is more than the t_{table} value. Therefore, it can be concluded that the average score of understanding ability between the experimental group and the control group is significantly different in the posttest. Interactive Conceptual Instruction Assisted by PhET Simulations has a positive effect on students' scientific consistency in physics material.

Table 7. The Mean Difference Test Result of Scientific Consistency Data

t value	Experimental Group		Control Group	
	Posttest	Pretest	Posttest	Posttest
t_{count}		0.39		7.77
t_{table}		2.40		

Improvement of Student's Scientific Consistency in Physics

Based on the pretest data on students' scientific consistency in the experimental group, the highest score was 61 and the lowest score was 17 while in the control group the highest score was 67 and the lowest score was 6. Meanwhile, based on the posttest data on students' scientific consistency in the experimental group, the highest score was 89 and the lowest score was 39 while in the control group the highest score was 78 and the lowest score was 28. The average pretest score of students' scientific consistency in the experimental group was 30.7 and the control group was 31.8 so that the difference between the two groups was 1.1. The average posttest score in the experimental group was 67.9 and the control group was 43.3. The average posttest score in the experimental group was greater than the average posttest score in the control group with a difference of 24.6. A comparison of the average N-Gain of students' scientific consistency in both groups is presented in Figure 2.

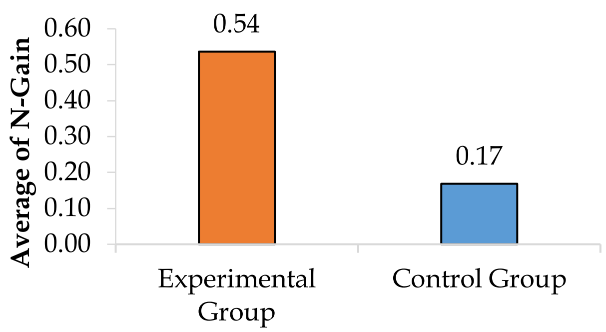

Figure 2. Comparison of average n-gain of scientific consistency overall

Statistically using the t test, there is no significant difference in the average score of the two group. However, after the treatment, there was an increase in the average score of scientific consistency in both groups. The average final test score in the experimental group was 67.88 or at level II with a moderately consistent category and the control class was 43.33 or at level III with an inconsistent category. The average final score in the experimental group is greater than the average final test score in the control group with a difference of 24.55. Statistically using the t test, there is a significant difference in the average value of the two classes. This shows that the application of interactive conceptual learning models assisted by PhET Simulation has a positive effect on students' scientific consistency. This finding is in accordance with the results of research from Nulhaq et al. (2016), Suyana et al. (2016), Maryana et al. (2017), and Siswanto et al. (2018) which show that interactive conceptual learning and multiple representation improve students' scientific consistency in physics subjects. Generally, students who are only presented information in the form of words (verbal) cannot remember most of the main ideas of the information and have difficulty in using what has been presented to solve new problems (Mayer, 1999, 2002). Most students also have difficulty in translating from one representation to another (Ainsworth, 2006). One of the functions of multiple representations is to complement other information and representations (Ainsworth, 1999). This will provide a rich context for students (Izsák & Sherin, 2003). Dual Coding Theory implies that a person will learn better when the learning medium used is an appropriate blend of verbal and nonverbal subsystems. The use of PhET Simulation will provide an opportunity for various representations to synergize with each other to optimize dual code memory. In the Cognitive Theory of Multimedia Learning proposed by Mayer (2003), it is stated that information received by humans through the senses will undergo three processes, namely selection, organization, and integration. Integration can occur when there is synergy between modes of representation through multiple representation. Multiple representation help in building a deep understanding of concepts when students integrate information from various representations presented (Ainsworth, 2006). This integration will construct a learning outcome that is then stored in long-term memory and ready to be used in the future or called upon when active learning takes place (Mayer, 2003). Therefore, students will more easily be able to represent a concept in various representations consistently.

From Figure 2, it can be seen that the average N-Gain in the experimental group was 0.54 with a medium category and the control group was 0.17 with a low category. The average N-Gain of the experimental class was greater than the control group with a difference of 0.37 and the average N-Gain of the two group was in different categories. The average N-Gain of the experimental group was in the moderate category, while the average N-Gain of the control group was in the low category. This shows that the increase in scientific consistency test scores of experimental group students who get interactive conceptual learning with PhET Simulations is higher than the control group who get interactive conceptual learning without PhET Simulations. This is in accordance with the results of research from (Nulhaq & Setiawan, 2016) which states that students who learn with multiple representations have better scientific consistency than without multiple representations. Students' representation ability can be influenced by the approach used by teachers in teaching concepts in the classroom (Kohl et al., 2007). In learning with PhET Simulations, students learn and various representations, such as verbal, diagrams, graphs, images, and mathematical so that they can understand the concept as a whole with these various representations. By using multiple representations in physics learning, it is facilitated to recognize and train multiple representation skills (Nulhaq & Setiawan, 2016). In Dual Coding Theory proposed by et al. (1991), it is stated that verbal information will be processed by the verbal subsystem sequentially while verbal information will be processed by the nonverbal (visual) subsystem simultaneously or in parallel. These two subsystems can function either independently, in parallel, or also integrated together (Sadoski et al., 1991). The use of various representations that are a combination of verbal and nonverbal (visual) through PhET Simulations will cause both systems to work in an integrated manner. This will maximize students' cognition process so that students can understand concepts and represent a concept in a variety of different representations consistently so as to improve students' scientific consistency.

In addition to analyzing the overall improvement in students' scientific consistency test scores, the researchers also examined this enhancement based on the modes of representation. There are four modes of representation in the test, namely verbal, pictorial, graphical, and mathematical. The average and comparison of the average N-Gain for each mode of representation in both groups is presented in Figure 3.

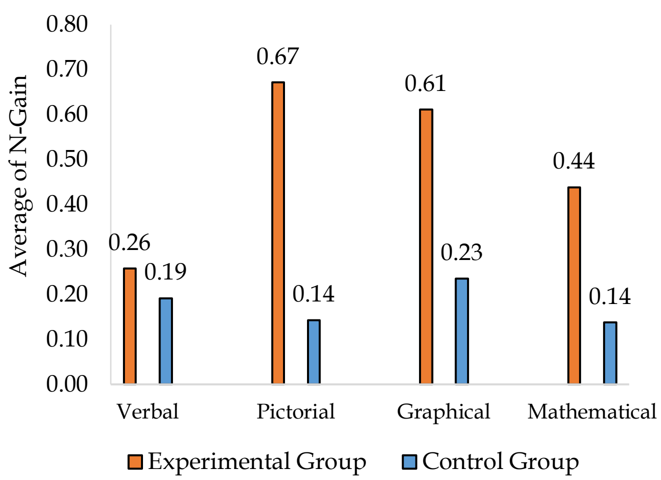

Figure 3. Comparison of average n-gain of scientific consistency for each mode of representation

Based on the data concerning the average scores for each mode of representation in scientific consistency during the initial test, it can be observed that in the experimental group, the order of modes of representation with average scores ranging from highest to lowest is verbal, mathematical, pictorial, and graphical. The highest average score for a mode of representation is found in the verbal representation mode, at 61.25, while the lowest is found in the graphical representation mode, at 32.99. Meanwhile, in the control group, the order of modes of representation with average scores ranging from highest to lowest is verbal, pictorial, mathematical, and graphical. The highest average score for a mode of representation is also in the verbal representation mode, at 51.33, while the lowest is found in the graphical representation mode, at 38.52. For the verbal and mathematical representation modes, the average scores in the experimental group are higher than those in the control group, whereas for the pictorial and graphical representation modes, the average scores in the experimental groupare lower than those in the control group.

Both groups share similarities in the modes of representation with the highest and lowest average scores. The verbal representation mode holds the highest average score in both group. This can be attributed to the fact that students in both groups were exposed to verbal representation dominantly in their pre-treatment learning, making them more comfortable and familiar with representing concepts or information in verbal form. However, the students appear to struggle with interpreting visual representations (pictures, images, graphs, and mathematics) and effectively conveying concepts or information through visual means.

The improvement in students' scientific consistency is also evident from the levels of scientific consistency. Based on the initial and final test data regarding students' scientific consistency, the number of students and the percentage of students at each level of scientific consistency were obtained as presented in Figure 4.

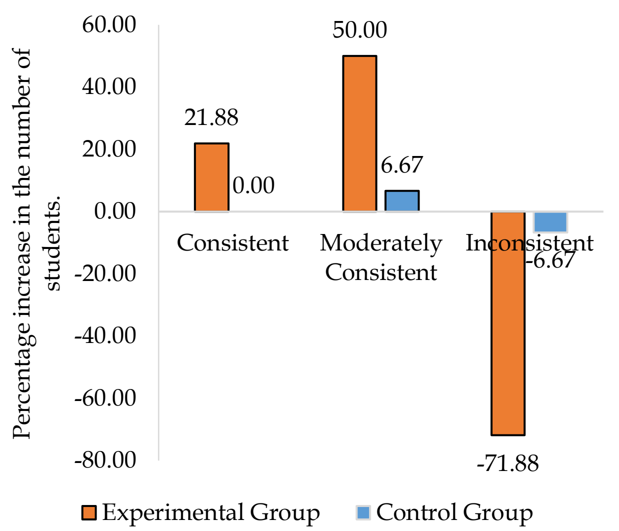

Figure 4. Comparison of percentage increase in the number of students for each level of scientific consistency

Based on Figure 4, it can be inferred that in the experimental group, there is a significant increase in the percentage of students at the consistent and moderately consistent levels, coupled with a considerable decrease in the percentage of students at the inconsistent level. Conversely, in the control class, there is a minor increase in the percentage of students at the moderately consistent level and a slight decrease in the percentage of students at the inconsistent level. However, the change in the percentage of students at the moderately consistent level and the decrease in the percentage of students at the inconsistent level within the control class is quite marginal.

Based on the data comparing the percentage of students at each level of consistency in the initial test, it is evident that in the experimental class, the percentage of students at the consistent level is 0%, at the moderately consistent level is 3.13%, and at the inconsistent level is 96.88%. Similarly, in the control class, the percentage of students at the consistent level is 0%, at the moderately consistent level is 3.33%, and at the inconsistent level is 96.67%. The percentage of students in both groups at each level of consistency is almost identical. A majority of students in both groups fall into the inconsistent level.

This observation aligns with findings from research by Nieminen et al. (2010) and Nurhasnawati et al. (2018), which indicate that a considerable number of high school students exhibit inconsistency in their understanding of physics subjects. This inconsistency is largely due to students' tendency to represent physics concepts or principles using only one or two forms of representation. Teachers infrequently utilize graphical, pictorial, or diagrammatic representations as alternative forms of conveying a concept. Instead, they lean towards verbal explanations. Consequently, students are not sufficiently encouraged to explain the same physics concepts using alternate representations (Monika et al., 2014). According to the Dual Coding Theory proposed by Clark et al. (1991), if information is presented solely in verbal or nonverbal form, it will be processed by the corresponding subsystem. This approach is unlikely to enhance the efficiency of brain memory utilization (Johan et al., 2018). As a result, students tend to represent physics concepts or principles only in the forms of representation they are familiar with due to the influence of their learning experiences.

Based on the data comparing the percentage of students at each level of consistency in the final test, it can be observed that in the experimental class, the percentage of students at the consistent level is 21.88%, at the moderately consistent level is 53.13%, and at the inconsistent level is 25%. Conversely, in the control class, the percentage of students at the consistent level is 0%, at the moderately consistent level is 10.00%, and at the inconsistent level is 90.00%. The percentage of students in both groups at each level of consistency differs. This indicates that the implementation of the interactive conceptual learning model with multiple representations has a positive and significant impact on students' consistency.

This finding aligns with results from studies conducted by Maryana et al. (2017) and Nulhaq et al. (2016). In the Dual Coding Theory proposed by Clark et al. (1991), it is stated that information received by humans will be processed by one or both subsystems within the cognitive system. If the information provided is both verbal (text and sound) and visual (images, pictures, graphs, and mathematical symbols), then this information will be processed by two subsystems: the verbal subsystem and the visual subsystem. This approach supports the concept of dual coding memory, ultimately enhancing the efficiency of brain memory utilization (Johan et al., 2018). Visual representation plays a pivotal role in communicating scientific concepts (Mathewson, 1999), aiding in the comprehension of phenomena that are too small, large, fast, slow, or not directly observable (Cook, 2006). The utilization of visual representation (images, pictures, graphs, and mathematical symbols) within the multi-representation approach assists in illustrating abstract phenomena that cannot be observed directly (Buckley, 2000). The amalgamation of text (verbal) and visual (nonverbal) components is crucial for fostering effective learning (McKay, 1999).

Conclusion

Based on the results of data analysis, research findings, and discussion that have been stated, it can be concluded that there is a significant difference in the scientific consistency between students who get interactive conceptual learning assisted by PhET simulation and students who get interactive conceptual learning without PhET simulation. The improvement of scientific consistency of students who received interactive conceptual instruction with PhET simulations is higher than the improvement of understanding ability of students who received interactive conceptual instruction without PhET simulation. The application of interactive conceptual learning assisted by PhET simulation should be done gradually and continuously in other physics material in order to obtain a higher increase in students' scientific consistency. Making representations of images and graphs by students should be done using computer assistance so that the representations produced are more proportional and do not cause errors in interpretation.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

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