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Changes in Students' Cognitive Structure on the Concept of Diffraction and Light Interference Using PhET Virtual Simulation

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ABSTRACT

The concept of diffraction and interference of light is one of the abstract concepts of physics. The process of light diffraction and interference occurs in the abstract. Learning about diffraction and light interference requires media that represent the events. Cognitive structures can represent the quality of students' understanding. Learning Physics is easier to understand through direct experience in the form of practicum. Abstract Physics concepts will be easier to learn with the appropriate visualization. One of the virtual practicums' media uses PhET virtual simulations to improve students' cognitive structure is measured using concept map questions and supported by description questions. The purpose of this research is to increase the cognitive structure of students by using PhET. This research is quantitative research and the experimental design used the experiment method. There are three groups in the experiment, that is a virtual simulation, a real practicum as an experiment class, and a control class. The results of the one-way ANOVA test on the concept map questions showed a significance value (p) <0.05, meaning that there were differences in cognitive structure between groups. The significance value (p) between the virtual simulation group and the real practicum group was 0.014, while the significance value between the virtual simulation group and the control class was 0.00, meaning that there was a significant difference in learning effectiveness between groups. Based on the data of the research concluded that physics learning assisted by virtual simulations can develop students' cognitive structures on the concepts of diffraction and light interference.

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Introduction

Students' cognitive structure can represent the quality of students understanding of physics concepts. According to Ausubel, students can be said to learn meaningfully if students can associate new learning material with existing cognitive structures (Mahardika et al., 2018). The cognitive structure or mental framework that a person forms by absorbing existing information from the environment and interpreting, classifying, and transforming (Sesto & Garc, 2021). The cognitive structure is another word for understanding. A cognitive structure can be interpreted as a form of a series of students' understanding in capturing the linkages between one concept and another (Sudarja, 2017).

Physics learning will be easy to understand through direct experience. The provision of direct experience in question is practicum activities in which there is a process of finding out and doing (Hermansyah et al., 2017). Practicum activities need adequate facilities and infrastructure. Not all physics experiments can be implemented, especially experiments involving abstract processes and concepts (Yusuf & Widyaningsih, 2019). The abstract concept of interference and light diffraction is the coherent superposition concept with the Huygens concept (Setiawan et al., 2019). In the process of learning the

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concept of diffraction and interference, namely introducing diffraction and interference patterns, many students fail to observe the important characteristics of certain patterns and identify differences between similar patterns (Susac et al., 2021). To study the concept of diffraction and light interference more optimally, it is necessary to have suitable media. Technology can help to learn abstract concepts, and multimedia learning can help students learn because it makes abstract concepts represent and easy to study abstract concepts (Cai et al., 2021; Rau, 2017).

Physics learning on abstract concepts and minimal facilities are using virtual simulation media. One of the easy-to-use virtual simulations is the PhET simulation. PhET (Physic Education and Technology) is an image media in the form of an interactive simulation of physical phenomena which is the result of research conducted by Physicists. PhET has combined experimental results and research results from physicists (Affandy et al., 2019). The use of PhET virtual simulations can improve student learning outcomes (Halim et al., 2021). Learning physics using PhET virtual simulations and Praxilab virtual laboratories can improve student performance assessments (Aseeri, 2020).

Changes in understanding of concepts at the microscopic level through direct experience, it is necessary to have virtual simulations to visualize microscopic concepts (Wibowo et al., 2021). This simulation helps students build microscopic-level concepts that cannot be demonstrated in real laboratories (Aminoto, T, 2020). This study aims to determine changes in the cognitive structure of students learning Physics with the concept of diffraction and light interference with the help of virtual simulations.

Method

This study used a quantitative method and uses experimental techniques. The subjects of this study were 136 students of class XI MAN 1 Jepara. The sampling technique used a simple random sampling technique because the sample members are taken from randomly selected individuals in a population so that all individuals in the population are considered homogeneous (Didik et al., 2019).

Table 1 shows the experimental design of this study. The design of this study consisted of two groups, each given a pre-test and post-test that treated with learning methods using PhET simulations and conventionally (Haryadi & Pujiastuti, 2020). This study was divided into three groups, the first group learning method using PhET virtual simulation, the second group learning method using real practicum, and the control group using the conventional learning method. With used different learning designs affect the knowledge structure of students (Farrokhnia et al., 2019).

Table 1
Experimental Design

Class	Pre-test	Treatment (Independent Variable)	Post-test
1	O_1	Virtual Simulation	O_4
2	O_2	Real Practicum	O_5
3	O_3	Conventional	O_6

Description:
O_1 = Cognitive Structure during pre-test 1st class
O_2 = Cognitive Structure during pre-test 2nd class
O3 = Cognitive Structure during pre-test control class
O4 = Cognitive Structure during post-test 1st class
O5 = Cognitive Structure during post-test 2nd class
O6 = Cognitive Structure during post-test control class

The use of concept mapping method is used in cognitive psychology and educational research to measure the impact of knowledge on cognitive structure (Hunzaker & Valentino, 2019). Concept maps help build better knowledge structures and represent a person's cognitive structure (Kinchin et al., 2019). Concept map scores can be used to represent student knowledge (Ganda et al., 2019). Concept maps display ideas in a hierarchical structure containing concepts and propositions which represent relationships between concepts (Machado, 2020). There are four components of the concept map assessment, namely; 1) Proposition (concept connection); 2) Hierarchy; 3) Cross Links; 4) Example. The data analyzed is the student's concept map scores. The scoring of concept map score is based on the concept map scoring rubric with the diffraction and light interference concept map master. Table 2 shows how to score the concept map.

Table 2
Scoring Concept Map

Concept Map Component	Score
Proposition (if right)	2 × number of proposition
Hierarchy (if right)	5 × number of hierarchy
Cross Links (if right)	10
Example (if right)	2 × number of example

Equation 1 shows how to calculate a concept map score.

$$NP = \frac{R}{SM} \times 100\% \quad (1)$$

Concept map assessment can be supported with some questions that are suitable for the contents of the concept map (Kinchin et al., 2019). This study used descriptive questions to confirm students' knowledge based on the concept maps they made. The total score of the concept maps of each student from the three classes was then analyzed using the one-way ANOVA technique with the SPSS application.

Result and Discussion

Cognitive Structure Based on Concept Map Score

The concept map questions were worked on by three classes consisting of Experiment 1 (Virtual Simulation) and Experiment 2 (Real Practical) and Control class. Student concept map scores in the pre-test and post-test obtained from the three classes were processed and then tested using the one-way ANOVA method. The results of the one-way ANOVA test are presented in Table 3.

Table 3
One-Way Anova Test Result

Kind of Test	Significance Value (p)	Interpretation
Homogeneity Test	0.06	If (p) > 0.05 then the data has the same variance (Homogent)
Anova Test	0.007	If (p) < 0.05 then the data has a different average cognitive structure

The use of multimedia in the learning process can help students learn more meaningfully, for example by integrating learning material with multimedia students can construct concepts in a cognitive structure that is interconnected and continuous (Lai et al., 2019). Meaningful teaching materials can develop students' knowledge (Agra et al., 2019).

In this study, concept maps are used to represent the cognitive structure of students. Table 1 shows the results of the one-way ANOVA test, the significance value (p) of the data homogeneity test is 0.06, meaning that the data has the same variance (Anindhyta et al., 2021). In this study learning using virtual PhET simulations was tested for homogeneity with a significance value (p) > 0.05. Meanwhile, the significance value (p) of the ANOVA test was 0.007, meaning that there was an average difference in the cognitive structure of the groups learning to use virtual simulation media, real practicum, and control classes.

The method used to determine the effectiveness of the learning media used was further tested namely the post hoc test. Further test results are presented in Table 4.

Table 4
Post Hoc Test (Further Test)

Class Comparison	Significance Value (p)
Real Practicum and Virtual Simulation	0,014
Real Practicum and Control Class	0,258
Virtual Simulation and Control Class	0,000

The results of the advanced test obtained the results of a comparison of the cognitive structure of students assisted by virtual PhET simulation and real practicum had a significance value (p) of 0.014 between real practicum classes assisted by virtual PhET simulation. While the comparison of the cognitive structure of students using virtual simulations and the control class has a significance value (p) of 0.000. The use of PhET simulation enhances the understanding of physics concepts. There is a significant difference in the post-test score with a value of (p) = 0.000 (Banda & Nzabahimana, 2021). Optical learning has been carried out with a different test resulting in a significance value (p) <0.001 (Wang et al., 2021), there is a difference in knowledge between the PhET virtual simulation experimental class and the control class.

The use of PhET simulation enhances the understanding of physics concepts. There is a significant difference in post-test scores with a value of (p) = 0.000 (Banda & Nzabahimana, 2021), Integrating PhET simulations into online learning effectively improves learning outcomes through their post-test results (Layson, 2022). The critical thinking abilities of students who learn with the help of PhET simulations are better than students who learn conventionally (Hidayatullah et al., 2021). The use of PhET virtual simulation media changes students' understanding (Shirley & Ellsworth-, 2018). PhET simulations increase students' understanding of physics concepts (Banda & Nzabahimana, 2022; Rais et al., 2020). PhET simulations can identify changes in students' understanding (Samsudin et al., 2020). Table 2 and Table 3 show that PhET virtual simulation on physics learning is more effective in developing students' cognitive structures. In addition to the results of the one-way ANOVA test and follow-up test, Figure 1 shows a graph of the average cognitive

structure of students in the virtual simulation group, real practicum, and control class.

Figure 1
Graph of the Average Cognitive Structure of Students Between Group

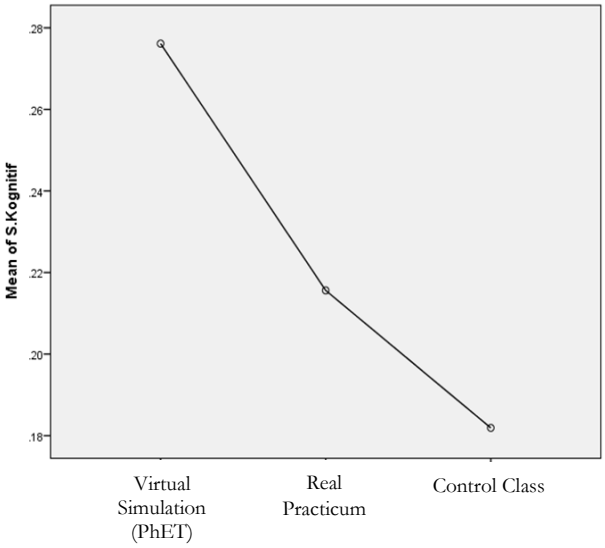

Figure 1 is a graph of the average cognitive structure of students between groups from the SPSS application, Figure 1 shows that the group or class that studied with the PhET virtual simulation had the highest average cognitive structure compared to the group that studied using real practicum and the control class. PhET virtual simulations make Physics concepts more dynamic and illustrative which effectively builds models of the knowledge structure of students (Saudelli et al., 2021).

Cognitive Structure Based on Score Description Question

The instrument used as a comparison of concept maps, students also work on description questions that are by the concept maps of students. The students' description values for each group were tested using the one-way ANOVA method. The results of the ANOVA test obtained a significant value (p) of 0.003. Based on the test results, the p-value <0.05 means that there is a significant difference between the groups (Liang et al., 2019).

Appropriateness of Concept Map and Description Test Result

The suitability of the results between the concept map and the description form test used the two-variant similarity test or homogeneity test using the SPSS application. The homogeneity test is used to find out whether there is a high enough relationship (Rati & Rediani, 2021), between concept map questions and description questions. The results of the data analysis are described in Table 5.

Table 5
Variance Similarity Test on Concept Map and Description Question

Class	Significance Value (p)
Virtual Simulation Class	0.152
Real Practicum Class	0.375
Control Class	0.343

The test used to determine student learning outcomes uses description questions (Wang et al., 2021). In addition to providing a concept map test, the data collection is also supported by a test in the form of an essay test (Pratama et al., 2020). Although these two types of tests have their characteristics, they both have the same variance so both can be used as learning evaluation tools.

Conclusion

Data analysis using the ANOVA test resulted in a significance value (p) between the virtual simulation group and the real practicum group of 0.014, while the significance value (p) between the virtual simulation group and the control class obtained a result of 0.00 meaning that there was a significant difference in learning effectiveness between groups. Based on the results of the data analysis it was concluded that the use of PhET virtual simulations can affect the cognitive structure of students.

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