The Experimental Experience of Motion Kinematics in Biology Class Using PhET Virtual Simulation and Its Impact on Learning Outcomes

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Article Info	Abstract
	This study aims to provide biology students with a motion kinematics experimental experience using virtual PhET simulations and explore the improvement of their physics learning outcomes. Pre-experimental (pretest-posttest experimental design) was conducted in this study, pretest-posttest was carried out before and after the learning treatment, while the learning treatment was motion kinematics experiment using virtual PhET simulation. The research sample was taken purposively, they were 24 students of the Biology Education Study Program, FKIP Mataram University who took Basic Physics courses. Student learning outcomes were measured using a test instrument. Learning outcomes data were analyzed descriptively with the average score of achievement or performance of students' cognitive learning outcomes on pretest and posttest, as well as n-gain analysis. In addition, statistical analysis (Wilcoxon test) was used to determine the difference in the average score of student learning outcomes between pre-posttest ($p < 0.05$). The results of the descriptive analysis showed that the average score of student learning outcomes increased from pretest to posttest with successive criteria from "less" to "good," an increase in student learning outcomes with high criteria with an n-gain score of 0.71. The results of the statistical test showed that there was a significant difference in the average score of student learning outcomes before and after the motion kinematics experiment using PhET virtual simulation. The results in this study provide a learning experience related to ways of conducting physics concepts that are more meaningful in the learning process that can be widely used in routine physics teaching in the classroom.
How to Cite	

INTRODUCTION

To achieve sustainable development goals, the world needs students who are skilled and interested in science, and they view science as supporting their future careers (de Jong et al., 2013; Thomas, 2014; Ünal & Kaygın, 2020). Therefore, studying science is very important for today's students. Through the deepening of science, they directly participate as informed and active members of society, and their way of thinking about science supported by scientific

skills helps them in making evidence-based decisions and also in improving problem solving skills in everyday life (Lin et al., 2021). The three elements of science in a broader context are related to the fields of Biology, physics, and chemistry, all of which are interrelated and support each other. For example, integration between the fields of physics and biology, the concept of kinematics of motion which is generally studied in physics is related to the concept of human body tissue, or the concepts of adhesion, cohesion, and capillarity related to plant tissue material (Toto & Yulisma, 2017). On this basis, they are usually taught to science students in their first year of higher education. For example, basic physics courses are taught to biology students and vice versa. In our current study is the experience of teaching motion kinematics in a biology class.

Applying science in our daily lives requires hands-on theory and practice. Experience learning science in both theoretical and practical contexts requires an environment that provides practical learning experiences through simulation (Feisel & Rosa, 2005), especially when it comes to abstract scientific theories. It is recognized that laboratory experiments for science learning are generally recognized, because they are an important element in the educational process (Chen, 2010) and science cannot be taught meaningfully to students without practical laboratory experience. Science laboratories can help students to acquire a positive attitude towards science if it allows them to engage in active and successful laboratory activities (Chen et al., 2014). Policymakers around the world recommend including scientific inquiry into learning at all ages. Indeed, investigation provides opportunities for students to interact directly with the material world by using scientific tools, models, and theories. Likewise, activities in science laboratories give students the opportunity to build their knowledge by experimenting, enable them to combine theory perception with laboratory practice, and enable them to develop their skills (El Kharki et al., 2021).

Science education is based on learning experiments in scientific laboratories, where theoretical principles are verified and teaching is given in a practical orientation (Cabedo et al., 2018). Physics is basically a science that is produced through observations, investigations, and experiments carried out by experts who develop laws, principles, concepts, and rules in the form of equations or statements (Zaturrahmi et al., 2020). Physics is generally taught for all science majors in the first year of study at the Faculty of Teacher Training and Education (FKIP) Mataram University. With the current condition of the Covid-19 pandemic, which is still the main factor, experiments in the laboratory cannot be carried out. Therefore, the University provides a learning experience to students by utilizing technology in the online learning system that has been developed. To support student interactivity and visualization of science learning concepts, lecturers are also encouraged to develop and or apply multi-mode technology that allows students to apply, one of which is learning simulation as a substitute for experiments in the laboratory.

For a long time, the influence of information technology and the internet on education has radically changed the perspective on laboratory science learning practices (Scanlon et al., 2002), where new laboratory forms have been developed. Web-based experiments or online experiments promote the involvement of learners in virtual environments, re-creating real experiences. It is a broad concept that includes many online experimental instruments, such as virtual laboratories, interactive videos and more (Restivo & Cardoso, 2013). In addition, it is generally accepted that digital instruments such as interactive simulations or online laboratories can positively influence learners' knowledge, skills and attitudes (Hassan et al., 2013; Kozma, 1994).

The use of virtual laboratories in scientific experiments can help overcome the physical limitations of face-to-face laboratories. Virtual laboratories are computer simulations that can

provide access and offer views (how to work) similar to traditional face-to-face laboratories (Guimarães et al., 2011), and is an environment where students can carry out learning activities (Stahre Wästberg et al., 2019). Virtual laboratories help students to engage in their proactive learning process and can improve academic performance (Diwakar et al., 2015). Today, virtual laboratories have evolved into interactive graphical online user interfaces where simulation experiments can be performed, where students can manipulate experimental parameters and explore their evolution (de la Torre et al., 2015). Our current work is aimed at providing a motion kinematics experimental experience in biology classes using virtual PhET simulations and exploring improving physics learning outcomes for students taking basic physics courses.

METHOD

The pretest-posttest experimental design was conducted in this study, the pretest (O1) - posttest (O2) was carried out before and after the learning treatment, while the learning treatment was a motion kinematics experiment using virtual PhET simulation. The research sample was taken purposively, they were 24 students of the Biology Education Study Program, FKIP University of Mataram who took Basic Physics courses, and were involved in the kinematics of motion material. Demographics (age and gender) of the sample were not considered because the researcher assumed that demographic aspects did not affect the effect of treatment on expected learning outcomes. Learning meetings outside the pretest-posttest are 3 times on the kinematics of motion material.

Aspects of learning outcomes that are measured are specific to cognitive learning outcomes (Bloom, 1956), namely at the cognitive level C2 to C6 (understanding-C2, application-C3, analysis-C4, synthesis-C5, and evaluation-C6). The instrument for measuring cognitive learning outcomes is in the form of an essay test, each cognitive level uses one item so that the number of questions used is five questions. This instrument has been tested for validity in different groups and found to be valid and reliable, so it can be used as a data collection instrument in this study. A standardized grading scale from the university is used where the lowest score is 0 and the highest is 100, this is divided into five groups of score criteria, namely 0-20 (poor), 21-40 (less), 41-60 (moderate), 61-80 (good), and 81-100 (very good).

Learning outcomes data were analyzed descriptively with the average score of achievement or performance of students' cognitive learning outcomes at pretest and posttest, as well as n-gain analysis (Hake, 1999) to determine the criteria for increasing student learning outcomes scores. In addition, statistical analysis was also used, namely the pair t-test to determine the difference in the average score of student learning outcomes between the pre-posttest, this analysis used the prerequisites for the assumption of data normality. The hypothesis being tested is the significant difference in the average score of student learning outcomes before and after the motion kinematics experiment using PhET virtual simulation. Each statistical test used a significance level of 0.05. Statistical analysis using SPSS 25.0 software.

RESULTS AND DISCUSSION

The results of descriptive analysis of student cognitive learning outcomes in motion kinematics experiments in biology class using virtual PhET simulations are summarized in Figure 1 and Table 1. Descriptively, it can be seen that there is a gap in student learning outcomes between the pretest and posttest. The highest score of learning outcomes in the pretest was 45.00 and the lowest was 12.00, while the highest score was 91.00 and the lowest

was 49.00. The results of the pretest showed that the average score of student learning outcomes was 22.25 with the criteria of "less," while the posttest increased with an average score of 77.10 with the criteria of "good." The increase in student learning outcomes scores with high criteria with an n-gain score of 0.71.
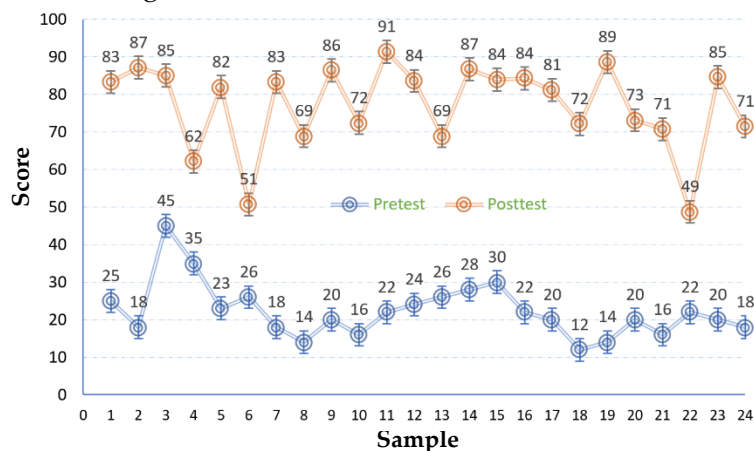

Figure 1. The results of descriptive analysis of student cognitive learning outcomes

Table 1. The summary of student cognitive learning outcomes

Intervals	Criteria	Pretest		Posttest		N-gain	Criteria
		F, (%)	Averages	F, (%)	Averages		
81-100	Very good	0, (0)	22.25	14, (58.4)	77.10	0.71	High
61-80	Good	0, (0)	(Less)	8, (33.3)	(Good)		
41-60	Moderate	1, (4.2)		2, (8.3)			
21-40	Less	11, (45.8)		0, (0)			
0-20	Poor	12, (50.0)		0, (0)			
amount		24, (100)		24, (100)			

The significance of differences in student learning outcomes between groups (pretest-posttest) was statistically analyzed using a pair t-test, this was preceded by a prerequisite test (normality assumption). The results of the normality test for the two groups of learning outcomes are presented in Table 2. Since the number of samples is less than 50, the Shapiro-Wilk normality test is used.

Table 2. Normality test results for two groups of learning outcomes data (assumed normality, $p > 0.05$)

Group	Shapiro-Wilk			Normality
	Statistic	df	Sig.	
Pretest	0.897	24	0.019	Sig < p (0.05), not normally distributed
Posttest	0.866	24	0.004	Sig < p (0.05), not normally distributed

The results of the normality test in Table 2 show that the data are not normally distributed, so the pair t-test uses a non-parametric test (Wilcoxon test). The results are summarized in Table 3.

Table 3. The Wilcoxon test results ($p < 0.05$)

		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
Score	Negative Ranks	0	0.00	0.00	-4.287	0.000
	Positive Ranks	24	12.50	300.00		
	Ties	0				
	Total	24				

The Wilcoxon test results in Table 3 show sig (0.000) < p (0.05) so it can be interpreted that there is a significant difference in the average score of student learning outcomes before and after the motion kinematics experiment using virtual PhET simulation. The results of our study have proven that motion kinematics experiments using PhET virtual simulations have a significant impact on improving student learning outcomes. This is in line with the results of a study by Ndihokubwayo et al. (2020) that PhET simulation is effective in improving student physics learning outcomes and is better when compared to learning that does not use PhET simulation. Through the PhET simulation, students better understand the physics concepts related to motion where some modes of motion display in the simulation are more visualized and even more interesting than the real conditions in a real laboratory. It supports cognitive processing of aspects of the material being studied and is found to be more effective in supporting learning interactivity (Correia et al., 2019). Students' positive perception of science learning is also built with PhET virtual simulation learning (Correia et al., 2019), this is a guarantee that learning can be carried out properly. The problem of student accessibility in distance learning mode is also solved by learning through LMS which is integrated with this virtual simulation (El Kharki et al., 2021).

Studies on the interest in using PhET virtual simulation have actually been around since 2005 and the trend of its application in the classroom continues to increase until now. A study by Zhang (2014) found a positive correlation between the application of PhET in the classroom and students' academic performance. This is one of the reasons for expanding the application of PhET virtual simulation in classroom teaching. In teaching physics in the classroom, for example to understand the concept of projectile motion, PhET is a virtual simulation which is considered the most effective technology to produce the best conceptual understanding in students, even when compared to phenomenon-based learning (Chinaka, 2021). This claim is in line with the results of a study that has long been stated by Yuen (2006), that computer-based virtual simulations are a learning necessity to encourage a more dynamic learning experience, and are able to construct students' thinking that is more solution. Finally, this is also in line with the results of our current study, that PhET virtual simulation has an impact on better student learning outcomes.

CONCLUSION

The results of the descriptive analysis showed that the average score of student learning outcomes increased from pretest to posttest with successive criteria from "less" to "good," an increase in student learning outcomes with high criteria with an n-gain score of 0.71. Statistically, the results of a study on the experience of motion kinematics experiments in biology classes using virtual PhET simulations show that there is a significant difference in the average score of student learning outcomes before and after the motion kinematics experiment using PhET virtual simulation. The results in this study provide a learning experience related to ways of conducting physics concepts that are more meaningful in the learning process that can be widely used in routine physics teaching in the classroom.

RECOMMENDATION

We recommend the use of virtual PhET simulation in classroom learning, not limited to lectures on physics material, but other materials. Future research also needs to investigate aspects of student involvement in the implementation of virtual PhET simulations.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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