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The Effectiveness of Teaching Materials for the Introductory Core Physics Course Based on the Use of PhET to Improve the Activity and Learning Outcomes of Physics Education Students

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Abstract: This study aims to examine the effectiveness of teaching materials for the introductory core physics course based on the use of PhET to improve the activity and learning outcomes of physics education students. The device was developed using a 4D model which includes define, design, develop and disseminate. The sample of this research was all 20 undergraduate students taking the core physics course. The data obtained in this study are in the form of activity data and student learning outcomes data. Student activity data obtained was then analyzed and adjusted to the value of activity criteria, while the increase in student learning out-comes was analyzed using the N-gain test. The results showed that the value of student activity ranged from 0.8 to 0.96 so that it was categorized as active and very active. The N-gain analysis shows that student learning outcomes have in-creased with a value of 0.73 to 0.77 and are in the high category. This means that the teaching materials for introductory core physics courses based on the use of PhET are effective in increasing the activities and learning outcomes of physics education students.

Keywords: Activity; Introduction to core physics; Learning outcomes; PhET

Introduction

Physics is a subject that is able to foster students' thinking skills to solve a problem that exists at school or outside the school environment (Sevtia et al., 2022; Susilawati et al., 2021). Physics is closely related to nature in the environment around us, because physics is a science that studies natural phenomena and their symptoms empirically, logically and rationally with a scientific attitude (Azizah et al., 2020; Doyan et al., 2022b; Rizkiyatullah et al., 2019).

In physics subjects there is core physics material. Core physics is invisible physics material, enabling educators to use interesting virtual-based learning media in order to be able to foster students' enthusiasm for learning so that students more easily understand the core physics concepts (Matsun et al., 2020; Suhartatik et al., 2020; Susilawati, 2014; Susilawati et al., 2021).

In the teaching and learning process, especially in core physics courses, it will be easier for educators to convey material using learning media (Hamka et al., 2019; Komikesari et al., 2020; Puspitarini et al., 2019; Rahmatullah et al., 2021; Susilawati et al., 2022). Learning media is a form of teaching that can support the teaching and learning process to make it more interesting, and able to stimulate students' interest to be more enthusiastic about learning in class (Alfurqan et al., 2019; Doyan et al., 2020; Dwijayani, 2019; Ramdhani et al., 2021; Simamora, 2020). The use of learning media in Core Physics courses is a part that must receive the attention of educators in carrying out learning activities (Doyan et al., 2022a; Khasanah et al., 2019). Therefore educators need to understand the learning concepts that

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will be used and choose the right learning media so that they can effectively achieve the learning objectives in the Core Physics learning process (Susilawati et al., 2023).

One of the learning media is virtual simulation media (Doyan et al., 2023; Susilawati et al., 2022). Virtual simulation media is a medium developed by experts to improve education through media created such as PhET (Physics Education Technology) which aims to increase students' understanding and learning outcomes (Halim et al., 2020; Inayah et al., 2021; Kusyanti, 2021; Mandagi et al., 2021; Perkins et al., 2006).

Learning to use PhET does not require a lot of money, because it only requires a computer and a PhET application to be able to run it (Durkaya, 2023; Perkins et al., 2012; Uwamahoro et al., 2021). All simulations in PhET are developed with research, so that they are in accordance with real events and concepts that will be built, besides that PhET has developed interactive simulations that provide benefits where there is an integration of computer technology into learning (Banda et al., 2021). PhET Simulations were developed to help students understand concepts visually. PhET can simulate in the form of using intuitive graphics and controls (Adams et al., 2012). PhET is a simulation that is easy to use and can be applied in class (Mahtari et al., 2020). The advantage of using this PhET simulation is that it can carry out physics experiments ideally where not everything can be done using real tools. The hope is that using PhET simulations in Core Physics can help students better understand and master the material.

Based on the description above, it is necessary to develop teaching materials for the Introduction Core Physics Courses based on the use of PhET to increase the activities and learning outcomes of physics education students.

Method

Teaching materials for the preliminary core physics course based on the use of PhET were developed using the 4 D model design (define, design, develop and disseminate) (Fraenkel et al., 2012). The sample used in this study was all undergraduate students taking the core physics course with a total of 20 people. To obtain data, researchers used observation sheets and tests as research instruments. Observation sheets are used to observe and observe student activities during the learning process. This is done by writing down scores according to the indicators that appear to students. The criteria for determining student learning activities can be seen in table 1.

Meanwhile, to obtain data on student learning outcomes, tests are used. Before the core physics learning tools are given, all students are given a pre-test which aims to find out the initial knowledge possessed by students taking the core physics course. Then a final test is given to find out the increase in the results of student activities and learning outcomes. The increase in learning outcomes is measured by the N-gain test using equation 1 (Doyan, Gunawan, et al., 2020). The N-gain calculation results ob-tained are matched with the N-Gain table. The N-Gain value consists of the high category (n-gain> 0.7), medium (0.70 >n-gain ≥ 0.30), and low (n-gain <0.3) (Doyan, Wardiawan, et al., 2020).

$$N - gain = \frac{s_{poost} - s_{pre}}{s_{max} - s_{pre}} \quad (1)$$

Table 1. Guidelines for Student Activity Criteria

Value Conversion	Qualification
0.90-1.00	Very Active
0.70-0.89	Active
0.50-0.69	Moderately Active
0.30-0.49	Less Active
0.10-0.29	Very Inactive

Result and Discussion

This study aims to examine the effectiveness of teaching materials for the introduc-tory core physics course based on the use of PhET to improve the activity and learn-ing outcomes of physics education students. The introductory material for nuclear physics consists of 6 chapters, namely: atomic nuclei, radioactivity, radioactivity decay, nuclear reactions, radiation interactions, radiation detectors.

Based on the research that has been done, data on learning activities and student learning outcomes are obtained. As for the aspects of student learning activities, there are eight aspects, namely: visual activities, oral activities, listening activities, writing activities, drawing activities, motor activities, mental activities and emotional activi-ties. The student learning activities are observed from the beginning to the end of learning.

At the beginning of the introductory core physics lesson, visual activity can be ob-served including paying attention to and listening to the lecturer's explanation of the material presented. Emotional activity can be observed through attention to learning such as students' responses and responsibilities when lecturers begin to organize them in groups. Visual activities such as paying attention to other groups when making presentations. Oral activity expressing a fact/principle, asking questions, expressing opinions on the introductory material of core Physics. Listening activities include listening to the introduction of core Physics material. Writing activities such as mak-ing a summary of the information obtained when studying the introduction of core Physics. The activity of drawing shapes and models of atoms. Such mental activity as being able to analyze and apply theoretical concepts, principles and applications of the atomic core. Emotional activity includes attention to learning and the courage to ask questions and work on problems.

The results of observing learning activities during meetings show that there is an average increase in student learning activities that are better. Learning activity data is shown in Figure 1.

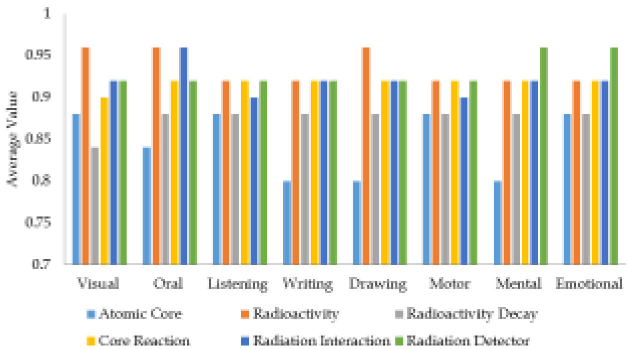

Figure 1. Student activity scores for each material in the introduction to core physics

Based on Figure 1 it can be seen that, in the atomic nucleus material the average value of each aspect ranges from 0.80 to 0.88. This shows that in the atomic core mate-rial, student activity when participating in lessons is in the active category. Further-more, in radioactivity material the average value for each aspect ranges from 0.92 to 0.96. This shows that in radioactivity material, student activity when participating in lessons is in the very active category. In radioactivity decay material the average value for each aspect ranges from 0.92 to 0.96. This shows that in radioactivity decay material, student activity when participating in lessons is in the very active category. In the core reaction material, the average value for each aspect ranges from 0.90 to 0.92. This shows that in the core reaction material, student activity when participating in lessons is in the very active category. In the radiation interaction material, the average value of each aspect ranges from 0.90 to 0.96. This shows that in the radiation interaction material, student activity when participating in lessons is in the very active category. In the radiation detector material, the average value for each aspect ranges from 0.92 to 0.96. This shows that in radiation detector material, student activity when participating in lessons is in the very active category.

Based on these data it shows that the application of teaching materials for introductory core physics courses based on the use of PhET can make students more actively involved in the learning process. This is in line with research that has been conducted by Ndihokubwayo et al. (2020) and Nyirahabimana et al. (2022) which states that students' learning activities increase positively after listening to lecturers delivering lectures using PhET simulations and providing efficiency in the learning process in class.

The active involvement of students is shown by their activeness in conducting group discussions, presentations, making summaries, daring to ask questions and express facts and opinions. Students are also more actively involved in visual activities, namely viewing and paying attention to PhET simulations that display introduc-tory material on nuclear physics such as atomic nuclei, radioactivity, radioactivity decay, nuclear reactions, radiation interactions, and radiation detectors. This is consistent with the characteristics of the PhET simulation, which is interactive, which means it is able to accommodate user responses, in this case students.

The learning outcomes data obtained consisted of pre-test and post-test scores. The pre-test and post-test values are shown in Figure 2. Based on Figure 2, it can be seen that the post-test scores obtained are higher than the pre-test scores.

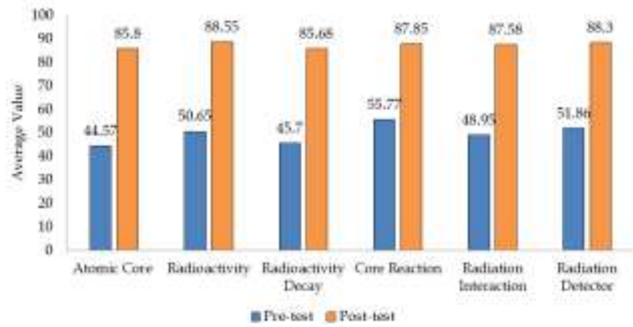

Figure 2. Pre-test and post-test values for each introductory core physics material

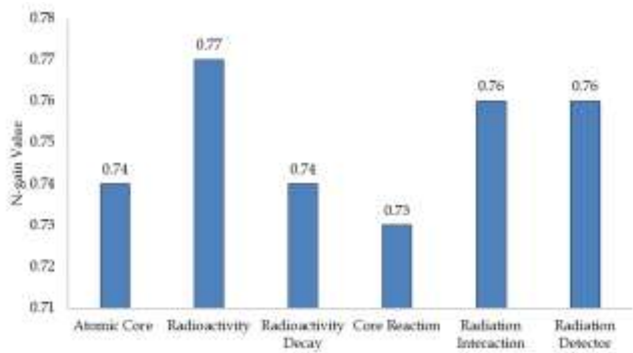

Figure 3. The n-gain value for each introductory core physics material

Furthermore, the increase in learning outcomes can be seen through the N-gain test. The results of the n-gain test analysis can be seen in Figure 3. Based on Figure 3, it can be seen that the n-gain values obtained for each material are 0.74 for atomic nucleus material, 0.77 for radioactivity material, 0.74 for radioactivity decay materi-al, 0.73 for radioactive decay material nuclear reaction, 0.76 in radiation interaction material, and 0.76 in radiation detector material. This shows that the value of in-creasing learning outcomes in each introductory material in core physics is in the high category.

Based on student learning outcomes during the learning process of teaching mate-rials for introductory core physics courses based on the use of PhET, it can be seen that student learning outcomes have increased. This is because the use of PhET in preliminary learning of core physics can certainly create learning that is active, creative, effective and fun (Perkins, 2020; Wendra et al., 2022). In this media, introductory material of core physics can be displayed which is abstract in nature and can be explained directly by this media so that students can easily understand the material. The simulation provided by PhET is very interactive and invites students to learn by exploring directly (Susilawati et al., 2022).

Conclusion

Based on the results of the analysis, it can be concluded that the value of student activity after learning using teaching materials for introductory core physics courses based on the use of PhET is in the active and very active categories. In addition, the value of increasing the learning outcomes of students who study using teaching materials for introductory core physics courses based on the use of PhET is in a high category. This shows that the teaching materials for introductory core physics courses based on the use of PhET are effective in increasing the activities and learning outcomes of physics education students.

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Conceptualization: S., and A. D.; formal analysis: S., A. D., and L. M.; investigation: S. All authors contributed to writing this article.

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Conflicts of Interest
No conflict interest.

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